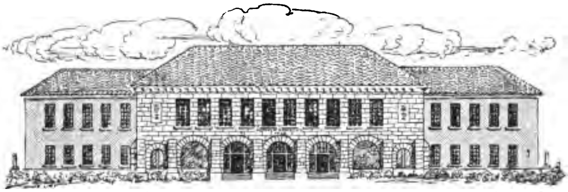
ROCKS AND MINERALS

FAIRBANKS



DEPARTMENT OF EDUCATION
LELAND STANFORD JUNIOR UNIVERSITY

STORIES

OF

Rocks and Minerals

FOR THE

GRAMMAR GRADES

BY

HAROLD W. FAIRBANKS, Ph.D.
Author of "Stories of Our Mother Earth," "Home Geography," etc.

EDUCATIONAL PUBLISHING COMPANY
BOSTON
NEW YORK CHICAGO SAN FRANCISCO

STORIES

OF

Rocks and Minerals

FOR THE

GRAMMAR GRADES

BY

HAROLD W. FAIRBANKS, Ph.D.
Author of "Stories of Our Mother Earth," "Home Geography," etc.

EDUCATIONAL PUBLISHING COMPANY
BOSTON
NEW YORK CHICAGO SAN FRANCISCO

PREFACE.

The great value of Nature Study in the primary grades is its training of the observational powers, and the cultivation of clear mental images. It should be made the beginning of geography.

In the grammar grades Nature study or elementary Science has an additional value because of the information which it conveys. It is an important feature of the new geography, which deals with a world of related rather than of isolated facts.

A scheme of education is fundamentally wrong which permits children to undertake the struggle for their existence entirely ignorant of the physical world with which they come in contact.

Although elementary science now has a standing in all well organized courses of study, there has been a tendency to make it one sided. It has been too often natural history alone, with little or no attention given to the physical conditions upon which life depends.

The study of nature in the grammar grades should not be differentiated as it is in the high school, but it should include an elementary treatment of all the natural sciences. The study of rocks and minerals, their origin, and the changes which they undergo in fitting the world to be a home for plants and animals, should equally with the elements of botany, zoology, meteorology, etc., be included in a symmetrical course.

Stories of rocks and minerals are fully as interesting as those of the other sciences, and in some respects have a

greater cultural value because dealing with factors and relations which call the imagination into play.

Books for the grammar grades, taking up the study of organic nature, are numerous, but up to the present time very little has appeared dealing with inorganic nature.

It is not the intention of the author to offer this little book as a systematic treatise upon minerals and rocks. Only the common ones are discussed, and in the treatment of these the effort has been not so much to impart information, as to arouse the interest of the pupil; to lead him to see in rocks and minerals and the changes which they undergo illustrations of the great processes which have shaped the earth and fitted it for habitation.

Rocks and minerals in themselves are often attractive. Many of them are intimately bound up with our every-day experiences. This is not all; they have not existed eternally as they are now. They all have had histories which are often of exceeding interest; histories which, when understood in even the most simple way, add greatly to the intelligence and pleasure with which we can study them.

The method employed in presenting the subject has been chosen, not because it is the logical one, but because it is believed to be the one most likely to make it attractive. The formal stating of definitions in advance has been avoided. The chemistry of the subject, as far as introduced, has been made as simple as possible. The minerals and rocks have been discussed and described by the aid of their physical properties.

It is hoped that the book, aided by a small collection of specimens, will be found of value in arousing the attention of both teachers and pupils to a much neglected but important field.

HAROLD W. FAIRBANKS.

Berkeley, Cal.

WHAT THE EARTH IS MADE OF.

Did you ever wonder what the world is made of and how it came to be as it is now? There is a great deal to learn, but when you have discovered how interesting it all is I am sure you will not become discouraged.

Beneath our feet is the soil which has had such a strange history. Yonder the men are quarrying blocks of stone to make some one a house. Down by the brook you can fill your pockets with all sorts of pretty pebbles, each one of which has a different story. Upon your finger there is a ring made of gold dug out of the earth by some miner. In your homes there are dishes of silver, copper, iron and porcelain, the materials for which came from different parts of the earth.

I am sure you would like to know about these and many other things, where they came from and how they were made. There are many kinds of minerals and rocks. Each kind has a story of its own, and will be very glad to tell it if you will only ask questions. You will find these stories as interesting as those of animals, of battles, or adventures.

Nature is our first mother. She has had many hard struggles in making our world what it is now. She has fitted up some portions of it so that they are very home-like, but others are still rough and barren.

She has been ever so long a time doing this; so long, indeed, that you could not count it in years if you spent your whole life trying.

If you look out over the fields you can see what Mother Nature has accomplished. There are green meadows, graceful trees, and bright flowers. Animals are feeding in the fields, birds are singing in the trees, and insects are humming about the flowers. How beautiful it all is!

But the earth has not always been like this. Many things have happened. The land where your home is has at different times been buried beneath the ocean. It has been shaken by earthquakes, and possibly there were fiery volcanoes near by which threw out lava and ashes. At one time it may have been a desert where nothing could grow, and at another time it may have been covered with ice for many years. Finally, long before our grandfathers came and settled here, Mother Nature succeeded in clothing the rough earth in a beautiful dress.

In making our earth Mother Nature had many substances to work with. We call these substances elements, because we cannot separate them into anything more simple. We have now discovered about seventy of these elements, but many of them are very rare.

From these substances Mother Nature made all the rocks and minerals. She is still at work in many places and if we learn how to look we may be able to discover what she is doing.

There was so great a quantity of some of these

simple substances or elements that Mother Nature had difficulty in disposing of them. However, she managed to use the most of the common ones in making the rocks of which there are many different kinds in the crust of the earth. The more rare substances, like gold and diamonds, which we greatly prize, she did not leave where they could be found easily, but hid them away in the rocks. We have to hunt long and carefully to discover them.

Mother Nature made the most of the minerals and rocks by melting the substances of which they are composed and mixing them in various ways. Some minerals she made by dissolving their components in water. The water distributed them in various places.

Beneath our feet wherever we go are the rocks and minerals of which we are speaking. They form the hard crust of the earth. Perhaps you live where the soil is deep so that you have never seen this hard crust, but you may be sure if you should dig far enough into the earth that you would find it.

We may call the hard rocks under our feet the skeleton of the earth. The soil is a soft covering which hides this skeleton as our flesh hides our own skeletons. The covering of soil makes the earth smooth and beautiful.

We must not forget that in most places the soil is very thin. There are many places where water has washed the soil away and left bare the rocky skeleton of the earth. If you walk far enough in any direction you are sure to come to the ocean or mountains, and

in the cliffs exposed in these places you can get a good view of the rocks. You will find them also in the beds of many of the streams. If you can find no solid rocks near your home there are certainly many pebbles, and these will tell you a great deal.

Do you not think that it would be very nice to know something about this old earth, about its minerals and rocks? We can make friends of them when they have told us their stories, and be very happy in their company.

THE BEGINNING OF THE EARTH.

Let us take a trip to the great volcano of Kilauea in the Sandwich Islands. This volcano is still active and a view of the crater upon its summit will help us to understand how our whole earth appeared a long time ago.

We climb the mountain and at last reach a point nearly a mile above the ocean where we can look into the crater. This is a great depression in the heart of the mountain, over three miles across. It is inclosed by precipitous walls of lava and is dark and forbidding in appearance. At different points in this crater there are steaming fiery vents where we can get glimpses of the red molten lava within.

We will descend into the crater and get as close as we can with safety to one of these openings. What a sight meets our eyes. Within a circling rim of lava there is a lake of fire. It looks much like a great pot of melted iron, such as we can see in an iron furnace when the ore has been roasted and the iron is ready to be drawn out in red hot streams.

The fiery lake is boiling. Occasionally jets of lava are thrown into the air amid clouds of steam which almost hide the lake. It rises and falls with ceaseless activity and sometimes it seems as if it would boil over the rim upon which we stand.

SURFACE OF A RECENT LAVA FLOW.

As we continue to watch it the lava finally becomes more quiet, and a crust begins to form over its surface. This crust loses its bright glow and turns quite black. At last the fire is hidden by the crust of cooled lava, but only for a time. After a few hours the crust cracks, and through these openings the red hot lava flows out and ingulfs the crust. Now the lake of fire boils up as before and we have to move back because of the heat and poisonous gases which fill the air.

Occasionally the whole floor of the great crater in which we are standing is melted and the lava, rising until it reaches the top of the walls, flows out and down the side of the mountain. It burns the forests and drives away every living thing. It may at times even reach the ocean. What a noise and hissing there would be, and what great clouds of steam when the fiery stream reached the water!

If we could go back to the lava stream after several months, we should find it hard upon the outside, but still almost too warm to walk upon. Perhaps in cracks here and there we could get a sight of the lava, still red hot beneath.

Now after having seen this great volcano of Kilauea, with its molten lava, can you not picture to yourself the appearance which the whole world once presented? A long, long time ago the earth was far hotter and more fiery than any volcano now existing. It was a glowing ball shining in the sky just as the sun does now.

The world began to cool upon the outside first, as you saw the lava cool in the crater. Then, perhaps, the crust would break up and melt again. Thus events went on until a permanent crust formed. For a long time this was not very firm. Fissures would open here and there through which lava and steam would escape. You can easily understand that no living thing could have existed upon the earth under such conditions.

The crust has been growing thicker and thicker and now the earth behaves as though it were nearly solid. But we know that, far within, it is still very hot, and in places in a melted condition, because of the lava which volcanoes throw out. The deepest mines do not reach more than a mile into the earth, but the farther the miners go the warmer they find the rocks.

When a hardened crust first formed over the earth there could have been no rivers or lakes or oceans. The heat of the rocks was so great that the water could not remain upon them, but as fast as it fell as rain it was sent back into the sky as steaming clouds. You know that if you drop a little water upon a hot surface like that of a stove it is quickly sent up in the air as steam.

The first crust of the earth was very rough and rugged, like the surface of the lava about a volcano. When it was cool enough for the water which fell from the clouds to remain, the water ran into the great hollows between the mountains and formed the lakes and oceans.

There was at first no soil, and without soil there could be no vegetation. Living things, with a simple structure, appeared first in the water, and as the rocks decayed to form soil these spread over the land. We would not have found the world a pleasant place in which to live at this time. There was a great deal of rain and but little sunshine, and with the lungs which we have we could not have breathed the air filled as it was with poisonous vapors. There were violent earthquakes and volcanic eruptions. The streams flowed over bare rocks and nowhere could we have found beautiful valleys such as we see to-day.

Such is a picture of what we believe was once the condition of the earth. It has at last cooled off and become so firm that we feel there is nothing safer than the solid land.

AN OLD LAVA FLOW ON WHICH SOME SOIL AND VEGETATION HAVE GATHERED.

HOW THE ROCKY CRUST WAS HIDDEN.

There are two things which finally hid the most of the rocky crust of the earth. I am sure you know what they are. One is water and the other is soil.

If we could drain all of the water out of the oceans, and then get a giant hose and wash all the soil off the hills and out of the valleys we would have our bare, rocky world again.

Where did the mud and dirt come from? Where was this soil made which has smoothed and rounded off the rocky skeleton of our old earth?

When Mother Nature had succeeded in getting the earth cooled enough for water to stand upon its surface, she found that there was enough of this substance to cover the greater part of its whole area. If the earth had been less rough and mountainous, or if there had been a little more water, no land would have been left exposed. With no land for us to live upon the whole history of our earth after this time would have been different.

The rocks forming the continents and islands which remained above the water were at first rough and sharp. We would have had a hard time trying to climb over them, but they did not remain as they were for any very long time.

Did you ever think that Mother Nature has two

forces at work in the world which are always doing opposite things? One of these is constructive; it makes rocks and minerals and builds up mountains. The other carries on a work of destruction; it makes the rocks crumble and tears down mountains. These forces are always fighting, like two bad boys. If one builds something, the other is sure to destroy it if he can.

Everything about us is changing. The animals are born, grow old, and die. Their bodies decay and disappear. Even the rocks which we can see now will not remain rocks always. Here is a piece of hard black lava which nature has just made. It is sure, however, after a time, to crumble and form a mass of clay.

As soon as the first rocky crust appeared upon the earth the agent of destruction began to work upon it. How did it soften and break the rocks in pieces?

First there were the rains. They fell upon the bare rocks and soaked into tiny cracks in them, slowly softening some of the minerals, even dissolving and carrying away little particles. The water was aided by an invisible gas, called carbonic acid gas. When dissolved in the water this gas is very active, and attacks many minerals.

Beside these there were heat and cold. In the day time the rocks became warm, and the little particles of which they were made swelled and pushed against each other. At night, the little particles became cold and shrank together. Thus, little by little, cracks

were formed, the minerals lost their hold upon each other, and the particles of many of them became softened.

Year after year, the heat and cold, the water and carbonic acid kept at work upon the rocks. At last much of the surface of the rocks which was exposed above the water of the oceans became covered with clay and sand. This was the beginning of the carpet of soil which has ever since covered the earth.

You must not think that all of the rocks which you find belong to this first crust of our earth. In fact, probably none of them do. Every little while during the long time that the earth has existed, the melted rock which we still find in the interior has been forced to the surface through cracks in the crust, and has flowed out over it. Every time a volcano breaks out more of this melted rock appears. We know that rocks are still being made because of what we can discover with our own eyes in the vicinity of volcanoes.

The rough lava fields near volcanoes appear very much as we believe the first crust of the earth did. This lava has, however, existed so short a time in many places that the forces of destruction have not yet been able to spread a carpet of soil over it. The forces which build up, as well as those that destroy, are even now working upon our earth, just as they did long ago. If we could live long enough we might some time see a forest growing upon the bare black field of lava where now there is not even a little plant of any kind.

If you will visit a quarry you can see the hard, fresh rock which underlies the soil upon which we walk. The heat and cold, the water and carbonic acid, have made it crumble upon the surface, but deep down they have not been able to get at it. The quarrymen throw away the softened rock, for it would not answer for buildings, and take the hard, fresh rock below.

We are going to study and become acquainted with these fresh minerals and rocks, but how are we to do it since Nature has buried them, in most places, with the covering of soil? Shall we be obliged to dig deep holes wherever we wish to get at them?

In the next chapter we shall see how Nature has uncovered the rocks for us. She has made it very easy for us to become acquainted with them.

HOW EROSION EXPOSES THE ROCKS TO OUR VIEW.

It was long, long ago that the first rocks were formed upon our earth. It was also long, long ago that the first soil began to gather upon these rocks as a result of their slow crumbling to sand and clay. Many new rocks have been formed since then, and some in the last few years, as a visit to a volcano will show us.

The most of the rocks are very old, and one would think by this time they ought to be buried under hundreds of feet of soil. Why is it that they are not buried so deeply? You have only to take a walk in almost any direction to come upon fresh, hard rocks. The most of these are not newly made rocks, but very, very old ones. How is it that they occur upon the surface?

Where are we most apt to find rocks? There are quarries where men obtain stone for our houses. Along the ocean cliffs the rocks are nicely exposed. If we enter the mountains we find but little soil, and on every side cliffs and walls of solid rock.

We can get an answer to our question, of how it is that the rocks are exposed in so many places, if we will but use our eyes well. Something is constantly removing the soil which would otherwise hide the rocks. This something is water. The water is at

THE STREAM HAS CUT THROUGH THE SOIL AND INTO THE ROCK BELOW.

work wherever it rains and snows, and from it we can get the information that we need.

After every heavy rain the brooks and rivers are loaded with mud. Dip up a cup of the muddy water and let it stand. After a time the water will become clear and you will find a layer of mud or silt deposited upon the bottom of the dish.

Walk out over the hills after a rain and you will see in many places the result of the work done by the water. The top of the soil has been washed away and here and there are little gullies dug out by the running water. Some of them are several feet deep. Where the water was swift it carried away fragments of rock which were embedded in the soil. These may some time be worn smooth and round and form the pretty pebbles which you find in the brook when the water is clear.

We can understand now what an important work the water is doing. It is taking away the crumbled rock which covers the hills, and is carrying it off to the valley. Some of it will in time reach the ocean.

Here is a gulch opened by the water to a depth of fifty feet. At the top the dark soil, with rotten stems and leaves mixed with it, is well exposed. Farther down the sides of the cut there is sand and clay. It crumbles easily, and if you throw a handful in the water, the water turns a muddy color and bears the most of it away down stream to some other place.

At the bottom the water is flowing over something hard. This is bed rock, the upper portion of the hard crust. The water has cut down through the whole

thickness of overlying soil, sand and clay, and reached this bed rock. It will cut a channel in this rock also, but much more slowly. You would never have known that there was rock here if it had not been for the work of the water.

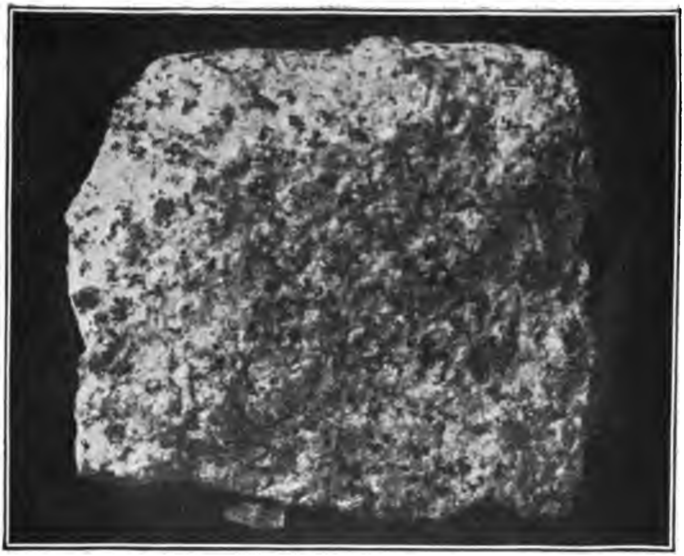
The river has made its cañon in the same manner. As we walk along the base of the cliffs in the cañon we study this exposure of the rocky crust and tell of what it is composed. If it were not for the river there would be no cañon and we would have no way of telling what was below the surface.

A walk along an ocean cliff shows us also how the water is uncovering the rocky skeleton of our earth. Here we can see that the soil is only a thin carpet over rocks which must reach down miles into the earth.

The crumbling rocks are trying to bury themselves ever deeper and deeper beneath the soil which is forming from them. In the valleys they are succeeding well because there the water does not run swiftly enough to carry away the softened rock. In the hills and mountains the water works faster because it runs more swiftly, and so keeps much of the rocky crust uncovered.

How fortunate for us that the water is doing this work. Otherwise we should have so much difficulty in finding where the minerals are, that we should probably go without the most of them.

We cannot get along without the soil, but we are glad that it does not hide the whole of the earth's rocky skeleton.



GRANITE.

WHAT WE FIND IN GRANITE.

Granite is one of the many kinds of rock in the crust of the earth. You have all seen granite, for it is a very common rock. It is used for buildings, for monuments, for paving streets, and in many other ways.

Granite is a rock which was formed deep within the earth ever so long ago. It is exposed now upon the surface of the earth because of the work of water. Granite was originally buried beneath other kinds of rock, but these have crumbled, been removed by erosion, and have left the granite upon the surface.

Here is a piece of fresh, hard granite just from the

quarry. It has a rough surface, and is speckled all through with grains of different colors. Some are dark, others light colored and glassy looking. Let us see if we can find out what they are.

We cannot separate the grains of the rock with our fingers. We shall have to get a hammer and pound the rock in order to break them apart. Their little points and angles interlock very tightly. Because the grains are thus tightly fastened together granite will bear a great weight, and is very useful in making large buildings.

If we examine the piece of granite carefully we shall see that there are many clear grains that look like glass scattered through it. These are very hard, for the point of your knife blade will not scratch them. Instead of being scratched, a little of the steel of the blade is left upon the grains. They are harder then than steel. If you can get a grain of this mineral out of the rock and break it you will find that it has a rough surface just like that of broken glass. It is not glass, however, for it will scratch glass, and is, therefore, harder.

This glassy mineral is quartz. It is the most abundant of all the minerals upon the earth. There are many kinds of quartz, which you will learn about later. There are only a few rare minerals, such as topaz, diamond, etc., that are harder than quartz. You may be quite sure that any glassy mineral that you pick up, which is so hard that you cannot scratch it with your knife, is quartz.

Quartz is found in many kinds of rocks. It is also found in veins carrying gold and other minerals. It has many uses, but we will talk about these later when we learn how quartz veins are formed.

Now that we can pick out the quartz in our piece of granite, let us find out what else it contains. Here is another mineral which at first you may think is quartz; but look closely and you can tell the difference without any trouble. The little grains have a light color, but they are not glassy. Their surfaces are not rough like the quartz, but are formed of smooth faces which reflect the light when you hold the specimen in just the right position.

The kind of light which is reflected from the surface of a mineral is its luster. Each mineral has a luster of its own. Quartz has a glassy or vitreous luster (vitreous means glassy), while the luster of this other mineral is more pearly.

We will now give a name to this mineral with the smooth faces. It is called feldspar. There are different varieties of feldspar, but the variety usually found in granite is called orthoclase. It is softer than quartz, and you will be able to scratch it with your knife blade, though not easily. Feldspar will scratch glass, but not as easily as quartz will.

If you break a piece of feldspar it will always part with smooth, bright faces or planes. We call these cleavage faces. Quartz usually shows no such faces.

Feldspar is used chiefly for making pottery, and

BIOTITE MICA.

MUSCOVITE MICA CRYSTALS.

especially for the glaze upon the outside. It is also the source of the most of the clay.

We now come to the third mineral in our piece of granite. This you can tell easily, for it is quite different from the other minerals. It is in the form of plates or scales, while its color is a dark brown. If you will use your knife blade you will discover that these plates are made of exceedingly thin scales which part easily. This mineral, then, has a very perfect cleavage.

The thin scales are elastic. By that we mean that they will bend and then spring back again. Although the mineral is quite dark, it has a bright luster. The luster is almost like that of a polished metal, such as iron. The mineral is much softer than quartz or feldspar, for you can scratch it easily with your knife.

We will call this mineral mica. It is almost always one of the constituents of granite. There are several kinds of mica, and you ought to know something about at least two of them. The one we have just studied is the dark variety. It is called biotite mica.

In some varieties of granite you will find no dark mica, but instead scales of light-colored, pearly mica. This has a bright luster like pearl. We call it muscovite mica.

The thin scales of this mica are often almost as clear and transparent as glass. In many places the mica is found in sheets, one to three feet across. Because of its clearness and the fact that fire will not easily melt

it, muscovite mica is mined and used for the windows of stoves. It is also ground fine and used to give the shiny appearance to many wall papers. Muscovite mica is sometimes wrongly called isinglass. This latter name belongs to gelatine in the form of thin, clear sheets.

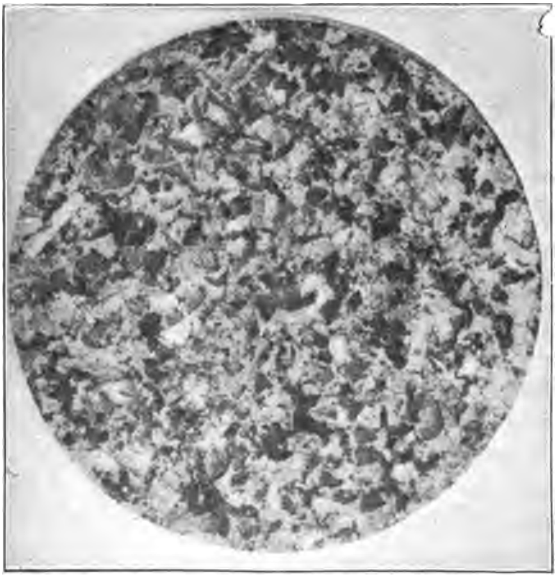
GNEISS.

We have now studied the three constituents of common granite: quartz, feldspar, and mica. Many granites contain another mineral, called hornblende, which we shall study in another chapter.

You have all seen the word gneiss. It is pronounced as though it were spelled nīs. This name is

given to a rock which contains the same minerals as granite, but they are arranged differently.

In gneiss the mica scales lie nearly parallel, and as a result the rock splits or breaks more easily in that direction. Granite breaks as easily one way as another.



GRANITE.

HOW GRANITE DECAYS.

Our soil has been formed through the decay of many kinds of rocks. Let us see how it is that a piece of granite can change to soil, and what transformations the minerals which we have found in it undergo.

The little grains in a piece of granite just from the quarry interlock arms and hold each other ever so tightly. We have to strike the rock a heavy blow with a hammer to separate them. The grains in a piece of granite which has lain on the ground and been exposed to the weather for many years are loose and have a rusty, dirty appearance. We can crush the rock now quite easily. What has brought about such a change in its appearance?

We have already learned how the rocky surface of the earth became covered with soil, and something of the agents which accomplished this. Different rocks contain different minerals and so do not decay in the same manner.

In the case of a piece of granite the heat of day and the cold of night made the little grains loosen their hold upon each other. Then into the crack thus formed between the grains went the water and carbonic acid, attacking the minerals themselves.

The quartz alone they could not injure. All they

could do was to loosen its hold upon its brother minerals. It does not decay or change when left exposed. The sands upon the beach are composed mostly of quartz grains derived from decomposed granite. The water has washed them about for thousands of years, and because they are so hard it has done little more than to round off their corners and make them smooth.

As the granite decays the feldspar goes through an important change. First it turns white and milky looking, and becomes softer. At last it crumbles and forms little grains and masses of kaolin. This mineral is soft and somewhat greasy to the touch when wet. It is only a pure variety of clay.

The mica also undergoes a change, but not as rapidly as the feldspar. It becomes softer and loses its bright luster. The scales of mica are light and easily carried away by the water. We can see them moving along the bottom of any clear brook in summer.

Besides those mentioned there is another agent which aids in breaking rocks in pieces. In every handful of the soil there are thousands of little organisms called bacteria. These have much to do with softening and changing the rock particles.

A piece of granite is at last changed in the manner that we have described, so that there remains in its place a pile of earth containing quartz sand, clay and scales of mica.

If we place a handful of this rotten granite in a dish of water we can separate the three minerals. The

quartz and mica will immediately fall to the bottom. The clay will remain suspended in the water for a time. We can pour the water off and so get the clay by itself, while further washing will separate the quartz sand.

Nature has separated these minerals for us upon a great scale, as you will see later. She has formed beds of each kind many feet in thickness. The sand

GRANITE CRUMBLING TO SAND.

is useful for making glass and mortar. The kaolin or clay is of great value in the manufacture of pottery. The clays which are not pure are used in making the coarser kinds of pottery and sewer pipe. The fine white clays are made into the most costly dishes and vases.

The scales of mica are, however, too small to be of any direct value to us. Sometimes they are mixed with quartz sand to form sandstone, but often they

crumble and help make the soil and the food which plants need.

Nature does the most of her work so quietly that we do not notice what is taking place unless we look very sharply. She works slowly also, but at last accomplishes results of great importance to us.

BLADED HORNBLENDE IN QUARTZITE.

LARGE CRYSTAL OF AUGITE SHOWING EIGHT SIDED FORMATION.

HORNBLENDE AND AUGITE.

I want to tell you now about two other minerals that are very abundant in many rocks. They look much alike, but you will not often find them occurring together in the same rock.

In many granites there is another dark mineral beside the mica. It varies in color from greenish to black and has smooth cleavage faces from which the light is reflected. If you attempt to scratch the mineral with a knife it does not appear to be as hard as feldspar. The color of the scratch or streak which the blade makes is greenish.

If you will examine your piece of granite carefully you will discover that this dark mineral has two sets of cleavage faces. These make an angle with each other of 124 degrees. That is, an angle equal to one right angle and nearly half of another. Hold the specimen up and turn it slowly, and as the light is reflected from the different faces you can see the angle at which they meet.

Sometimes hornblende takes the place of all the mica in granite. Then we call the rock hornblende granite. You remember that common granite contains quartz, feldspar, and mica. Sometimes you will find a rock that has the general appearance of granite, but contains only hornblende and feldspar. Such a rock

we call syenite. This rock, which has been known for a long time, is named after Syene, a place in ancient Egypt where it was quarried.

The mineral which you are most likely to get confused with hornblende is called augite. These two minerals are very much alike in color and hardness. Augite, like hornblende, has smooth cleavage faces, but they meet at an angle of ninety degrees; that is, a right angle. This latter fact will help you to distinguish them. Hornblende crystals differ from those of augite in being usually more slender, and in having four or six sides, while augite has eight.

Another thing which will help you to tell these two minerals apart is that hornblende is more fond of the society of quartz than is augite. You will not often find augite in rocks, like granite, that contain quartz.

Augite is found most commonly in rocks that are dark and heavy. They do not look at all like granite. One of these rocks is called gabbro. This is a queer name, is it not? It is an Italian name and was first given to the rock in Italy. The important minerals in gabbro are feldspar, augite,and iron ore. It is the iron that makes the rock so heavy. The chief components of the rock, augite and feldspar, are usually in large grains and you can readily tell them apart. We cannot call these grains crystals, for they are irregular.

The feldspar is a different variety from that in granite and is known as labradorite or anorthite. It is often darker than orthoclase feldspar and you will be

able, if you look closely, to detect upon the bright cleavage faces fine parallel lines. These are not found upon orthoclase. Labradorite often shows a beautiful play of colors. It was named from Labrador, where the finest specimens were found.

Diabase is the name given to another dark rock which contains the same minerals as gabbro. The rock is, however, usually fine grained, so that you will find difficulty in distinguishing the minerals. The rocks which we have been talking about are of igneous origin. They were once in a melted condition and at that time were forced up through fissures, the material forming them cooled, and after a time erosion exposed them.

We have found how closely related hornblende and augite are, and how much they look like each other. You might also be interested in knowing that augite sometimes changes into hornblende.

Hornblende and augite are members of large families. Hornblende belongs to the amphibole family. Other members of this family are called actinolite, asbestos, tremolite, etc. We shall study some of these later. The family to which augite belongs is called the pyroxene family. You will want to know more about this family if you study rocks very much.

A PEBBLY BEACH.

SAND AND PEBBLES.

Here is a handful of pebbles. They were found in the bed of the river. How round and smooth they are! They exhibit many colors; black, gray, green, yellow and red. They are very hard, also, for we cannot scratch them, and a heavy blow with a hammer is needed to break one in pieces.

We want to learn something about the history of these pebbles, where they came from and how they were made. Since they came from the river, water must have had something to do with them.

We shall have to go far away to the hills or mountains to find where the pebbles started. And the strange thing is that when we get there we shall not be able to find any pebbles. The beds of the creeks are filled with rough and sharp-cornered stones. At the bottom of the cliffs there are great pieces of these rough fragments of rock. They have all tumbled from the cliff above, and if we watch a little time we may see one fall.

We have learned in a previous chapter how the rocks crumble to sand and clay. Many rocks do not decay easily, but are, nevertheless, filled with seams and cracks. The water gets into these, and after freezing forces the rock apart. The roots of the little plants, and even trees, go down into the cracks in

their search for food and water. They pry the rocks still farther apart.

As a result of these things the rocks are continually falling from the cliffs. Some of the pieces roll into the creeks beneath and are borne away down stream. The creeks run past cliffs in which are different kinds of rock, and so we find these different kinds in their beds.

Down the stream the rocks go, rolling over and over in the swift current. Their corners hit upon each other, and upon the bottom, and are ground off. They are many years in traveling down the creek. In the summer, when the water is low, they rest. When the floods of winter come they are picked up again and carried still farther.

The pieces of rock are being worn smaller as they move along. The soft ones are ground to sand and clay. These fine materials are borne along more rapidly, and are not long in reaching the quiet waters of the lake or ocean, where they are dropped.

The hard fragments resist, and at last, in the form of smooth, round pebbles, reach the river-bed where we found them. The stream has been many years making these shining pebbles from the rough rock fragments. Each pebble has come from a different place and has a story of its own. Quartz is usually the most resistant material in rocks, and as a result most of the pebbles are different varieties of this mineral.

These pretty pebbles will, another winter, be car-

ried still farther down stream and others will take their places. They may some time reach the ocean if the stream is swift and they do not wear away.

The waves of the ocean are also making pebbles, but in a somewhat different manner. The water is always dashing against the rocky cliffs. What a wild sight it is to see a great wave strike the rocks and the spray fly high in the air! The stoutest ship cannot long stand the force of such waves.

Do you think the waves are doing any work? As each wave rushes shoreward it picks up the smaller pieces of rock from the bottom and hurls them against the cliffs. In this way the cliffs are slowly undermined and frequently large masses of rock break away and fall into the water.

This gives the waves new material to work upon. The pieces of rock are washed around and around, and are broken up into smaller ones. Their corners are broken off, and the harder ones at last are made into smooth pebbles. Have you never been upon a pebbly beach and heard the noise made by the pebbles as with each wave they are rolled up and down the beach?

The waves sort the fragments of rock. The pebbles are gathered in one place and the sand is carried off to another, while the fine clay floats far out into more quiet water.

The grains of quartz from a piece of crumbling granite are much alike in color and size and have sharp angles. Take a handful of beach sand and

examine it with a microscope. The grains are smooth and of about the same size, but of many different tints. Each little grain can tell a different story. Each one had a home in a different place.

Do you know what name we give to large pebbles? They are called cobble stones. Those of you who live in the city know what rough pavements cobble stones make.

A very large rock fragment which has been rounded like a pebble is called a boulder. The water has a much harder time moving boulders about and in making them smooth. There are ever so many of them, however, as you can discover by hunting along the river or ocean cliffs.

ROCK FORMED OF SAND AND PEBBLES.

HOW ROCKS ARE MADE.

We have learned that rocks decay and crumble. We have learned that water is moving this waste material from the highlands to the lowlands.

How are rocks made? What is the history of some of the common rocks, those which we see every day? We would like to know more about them.

A long time ago, as you have already been told, our earth was a fiery molten mass. As it began to cool there was formed a hard crust which we call rock. Those which have been formed from melted material we call igneous rocks. Granite is an igneous rock, so also is gabbro. These were formed far below the surface of the earth.

To those igneous rocks which were formed upon the surface of the earth we give the name of lava. They are also called volcanic rocks because many of them have come from volcanoes. We shall learn more about such rocks in another lesson.

Igneous rocks are not the only ones upon the earth. We find many others that have never had anything to do with fire. What becomes of the mud and sand and pebbles which the water is forever engaged in making and washing about?

Night and day the rivers over the whole world are engaged in bringing mud and sand to the ocean. The waves are tearing down the shore and making more waste. What is done with all this material?

Ponds and lakes are often completely filled by the waste from the land. I am sure many of you have seen a delta at the upper end of some lake. Where does the delta material come from?

Perhaps you have seen how muddy the water of the ocean or lake becomes during a heavy storm. The currents of water sweep along the shore, taking up the fine particles of sand and clay and bearing them far out.

The pebbles are not moved far. They slowly gather and form thick beds along the shore. A little distance from the shore where the water is more quiet we find the bottom composed of sand. The finer sand and mud float much farther out, and when the water becomes quiet after the storm they sink to the bottom. We can tell what the bottom is composed of even

where the water is very deep by the aid of a machine called a dredge. This is let down to the bottom and when it is hauled up it brings some of the material forming the floor of the ocean with it.

The water currents have sorted the waste from the land, leaving the coarse near the shore and taking the finest material the greatest distance out. The water is doing this work continually although with greater rapidity when the currents are strong. It has been working in the same manner ever since there were oceans, and lakes, and rivers. Would you not think that by this time beds of great thickness must have accumulated over the ocean bottom? This is really what has taken place. Some of these beds are many thousands of feet thick.

Perhaps you are wondering how it is that we know so much about these beds, as we cannot go beneath the water to study them. It is because of movements of the earth's crust. In many places what used to be the floor of the ocean has been lifted far above the water. We now find beds of pebbles, sand and clay, often containing shells, upon the sides and tops of the mountains. We can examine them in the cañons which running water has excavated.

These different beds remained a long time below the water before they were elevated. The materials of which they are composed slowly became pressed together and changed to what we call rock. Some rocks are very soft and crumble in our fingers. Others we need a hammer in order to break.

We can learn something about the condition of the material in the bottom of the ocean by studying a mud flat when the tide is out. How smooth and even the surface is! It looks hard, but try to walk upon it and you will sink deeply in soft mud. This is much like the mud collecting in the ocean bottom far from shore. If we visit this flat after a winter storm we may find a layer of sand spread over the mud. The stronger currents during the storm brought the sand and carried the mud somewhere else.

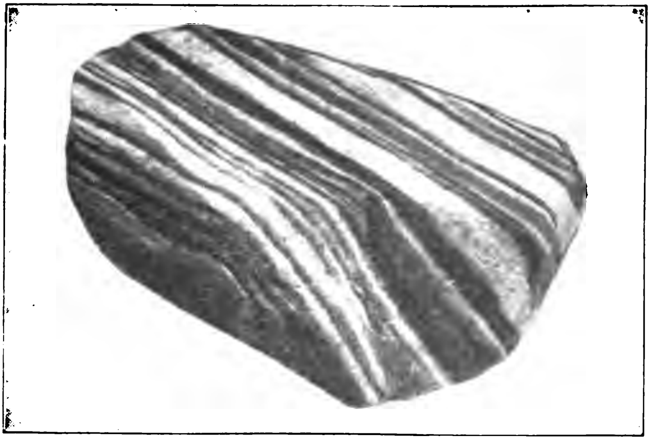
At another time some small pebbles and shells may be washed onto the flat. We can understand from this that the portion of the bay occupied by the mud flat is filling up. It may become dry land some time. This land will be composed of layers of mud or clay, sand and pebbles. So much waste is brought by the rivers into some harbors that they are fast filling up. Machines called dredgers are kept at work scooping up the mud in order to keep the water deep enough for the ships.

You will see in many cliffs, where the rocks are exposed, layers of hardened clay, sand and pebbles. They are just like those being formed in the water at the present time, and we are sure for this reason that they were made by the water and that the ocean once stood where now there is dry land.

These materials, then, about which we have been talking constitute the rocks formed by the water. This material we call sediment, because it is that which settles to the bottom.

The rocks formed from these sediments we call sedimentary rocks.

You understand now something about two kinds of rocks which we are going to study,—those formed through the action of fire or igneous rocks, and those formed by water or sedimentary rocks.



BANDED SANDSTONE.

A PEBBLY CONGLOMERATE.

THREE KINDS OF SEDIMENTARY ROCKS.

We shall now try to find out what we can about the rocks made from the sediments which were described in the last lesson.

We take up first the rock formed of pebbles. Here is a picture of such a rock. It is called a conglomerate, because it contains a mixture of many different kinds of rock fragments.

The fragments, or pebbles, do not constitute the whole of the rock, for the spaces between them are filled with sand. The grains of sand have been pressed tightly together and cemented with a little lime which the water seeping through has brought them. The sand forms a matrix for the larger fragments and holds them firmly.

A conglomerate which contains smoothly rounded pebbles is sometimes called pudding-stone. You can see that it has come to have that name because of a fancied resemblance of the pebbles to the plums in a pudding.

When a conglomerate is composed of angular pieces of rock we call it a breccia. In this case the rock fragments were not rolled around long enough by the water to have their corners worn away before they were buried under new materials in the bed of the ocean.

The beds of sand deposited in successive layers

upon the ocean floor have been changed to rock in a manner similar to the conglomerate. Beds of sand alternate with those of clay and of pebbles. This is the result of changing currents, as you have already learned.

Many years passed during the accumulation of the bed of sand which now appears before us in some cliff as a stratum of sandstone. As other beds were formed over this one their weight pressed the grains close together. Then, at last, when a portion of the ocean-bed, where the sand was accumulating, became land, water, carrying lime in solution, crept slowly through between the grains of sand and cemented them together.

They now form such a firm rock that you will need a hammer to obtain a piece. All that you can see in a specimen which you may be able to break off is grains of sand and little dark scales of mica. In most sandstones there is also a little clay. Crush a piece of the rock and cover it with water. The water will become muddy looking because of the clay.

Sandstone which has stood in buildings for many years often shows signs of crumbling upon the corners. This is because the raindrops which fall upon it carry a little carbonic acid which dissolves away the lime cementing the grains, thus allowing them to fall apart. Sandstone will crumble much quicker than granite. It will not bear as heavy a load as granite, because the grains do not hold each other so tightly.

Sandstone is of many different colors. It is red or gray or brown or yellow. These colors are given by a small quantity of iron scattered through the rock. Sandstone is easily quarried and cut, and is useful in many ways. Mention some of the ways in which it is used.

Now let us see what changes the clay goes through in becoming rock. The materials of the clay, like those of the other sedimentary rocks, have undergone great pressure. This has changed the clay to a soft rock of dark gray or black color.

The rock breaks most easily in one direction, forming thin, irregular layers. A rock which breaks in this manner we call shale, and when it is formed of clay we call it an argillaceous or clay shale. The word argillaceous means clayey. Clay shale is usually so soft that we can break it in our fingers. When exposed to the sun and rain clay shale soon softens and crumbles to a mass of clay.

Upon some beds of sandstone and shale there are ripple marks which are just like those which we see at the bottom of a quiet pond or lake. These marks tell us that the rocks were formed in shallow water. Sometimes, too, there are tracks of birds upon the surfaces of these rocks and even impressions of raindrops. These things tell us that long ago it rained as it does now, and that there were birds that waded around upon ancient mud flats, leaving their footprints for us to puzzle over.

SLATE, MICA SCHIST, AND QUARTZITE.

The crust of our earth has been much disturbed at different times since it was first made.

Layers of rock which were formed from sediments deposited at the bottom of the ocean were at first nearly level. If we examine some of the rocks made from these sediments, which are now exposed in the ocean cliffs and cañons, we shall find that in many places they have been tilted and sharply folded. Sometimes they stand vertical.

Because of disturbances of the crust, portions of the beds of sand and clay upon the ocean bottom were pushed far down into the earth. There heat and pressure made such changes in their character and appearance, that now, when again exposed at the surface as the result of elevation and erosion, we hardly know them.

Deep down in the earth the pressure is very great. The rocks there have to hold up the weight of those above. Besides this the earth grows warmer as we go into it. If we could go far enough we should reach a region where the heat is sufficient to melt the rocks.

The soft shales and sandstones that are folded and pushed down into this hot region are baked hard and their components are changed. The shale, which

before would have crumbled easily in your fingers, has become hard and difficult to break. It splits into thin, regular layers which are quite smooth. We call this rock slate. You are all familiar with this rock in the form of the black slate, with the light wooden frame, upon which many are accustomed to write and figure.

The most important use of slate is, however, in making the roofs of houses. If we could visit a quarry we might see the men getting the slate out in great slabs. It is afterwards split into thin layers and cut down to the proper size.

When a bed of shale deep in the earth is exposed to heat still greater than that to which slate has been exposed it is changed to a rock having no resemblance to the original shale.

This new rock is composed of a mass of shining mica scales and splits easily because of their nearly parallel arrangement. The surfaces of this rock are not so smooth and regular as those of slate. To a rock which breaks easily in one direction, but with irregular faces, the name of schist is given. When it is composed mostly of mica we call it mica schist. In most mica schists you will find a little quartz also.

The shale has now been so changed that we might almost call it an igneous rock. It was composed of fragments before being heated. Now it is crystalline. There are new minerals in it that were not there before. These were made by heat out of the material of the shale. We apply the term metamorphic to

such rocks. This word means changed. You cannot imagine two rocks with greater contrast than the soft, crumbling shale and the schist, with the glittering mica scales, and yet both have been made from soft clay.

Now let us see what happens to the sandstone when it gets into the region of heat within the earth. The sandstone is changed to one of the hardest and most enduring of rocks. The little grains of quartz in the sandstone are pressed together and almost melted, so that they form one solid mass of quartz. A sandstone that has been changed in this manner we call a quartzite. In many pieces of quartzite you can still see traces of the grains of which the rock was once composed. Occasionally the grains are quite distinct, like the granules in a lump of sugar. Then we call it granular quartzite.

The most of the hard pebbles which you find upon the beach are quartzite. They are of all colors — black, brown, red, gray, and white. Some specimens are quite glassy, others are dull in appearance.

We are going to learn more about the formation of quartz in a later chapter. The quartzite of which we have been speaking has had a very different history from that of the mineral we call quartz, although the two sometimes look much alike and are composed of the same substances.

A SMALL VOLCANO.

THE STORY OF VOLCANIC ROCKS.

Igneous rocks are those which have been formed through the action of fire. They were once in a melted condition. We have already studied some of these rocks, such as granite and gabbro. They were formed within the earth.

The rocks which we are going to study now are also of igneous origin, but they were formed upon the surface. As many of them have come from volcanoes we call them volcanic rocks. These rocks, resulting from the cooling of molten material upon the surface, have a very different appearance from those made within the earth.

We are sure that volcanic rocks were once in a melted state, for many of them look much like the slag from a furnace, or the clinkers from a hot coal

fire. Besides this, eruptions of lava occasionally take place at the present time in different parts of the world. People have seen streams of melted rock burst out of the volcanoes and flow down their slopes. These red hot lava streams resemble the streams of melted iron which are allowed to flow from a furnace when the men are ready to make a casting.

In some parts of the world there are few or no igneous rocks to be found upon the surface. Over much of the Mississippi valley the rocks are of sedimentary origin. In other parts of the world, especially in mountainous regions, you will find a large proportion of the rocks to be of igneous origin. Where mountains occur the crust of the earth has been much disturbed and broken, and that is why there are many igneous rocks in such places.

Have you ever seen a piece of lava? It is hard and rough and often full of little roundish holes. Some lavas are so full of holes that they feel as light as wood. Such a rock is called scoria. If the rock is very light we give it the name of pumice. You have all seen the pieces of pumice that are obtained at the drug stores and used for cleaning purposes. Pumice contains so much air that it will float upon the water for a long time. Sailors sometimes report the sea covered with pumice in the vicinity of volcanic eruptions.

Would you not like to know why the molten lava flows out upon the surface? It is an interesting story.

Away down below us, thousands of feet, the rocky material of the earth is still slowly cooling. When molten rock cools it takes up a little less space than it did when hot. The outside of the earth has been cold for a long time, and as the inside continues to cool it becomes smaller, letting the outside settle down a little here and there. In this way wrinkles are formed upon the earth like those upon an apple which has dried out.

The wrinkles are the beginnings of mountains, and the hollows between them are valleys. Cracks are formed in the crust where there are wrinkles, and as the earth settles down some of the hot melted rock below it is pressed up through the cracks until at last it flows out and over the surface. We think that this is one of the reasons for the formation of lava.

Another reason is that water is soaking down through the rocks continually. In some places it follows the cracks down until it gets to where the rocks are very hot. There some of the water is changed to steam and is mixed with the molten material.

When water becomes steam it requires much more space than it did before. The steam thus formed deep within the earth has no ready means of escape. It must expand, and in trying to make room for itself may cause a volcanic outbreak. If the pressure of the steam becomes too great it forces its way up through the rocks where they are weakest, and at last reaches the surface, bringing with it more or less of the molten material from below.

The lava may flow out quietly from a fissure and, if there is much of it, spread over hundreds of square miles of the surface.

The lava may be forced out by the steam with explosive force from a small opening. The fragments of cooled lava will then collect about this opening and in time, if the eruptions continue, will build up a mountain. In the center of the top of such a mountain is a depression, shaped like an inverted cone, through which the lava is forced out. This is called the crater.

Some of the highest mountains of the globe have been made in the way that we have described. Can you name any of them?

The round cavities which we find in lava were once occupied by steam. Where there was much steam the lava is very porous.

A volcano is a sort of safety valve for the earth, for through it the pent-up steam and other gases find a way out. They may do this so violently, however, as to produce heavy earthquakes. Volcanoes help us to understand something about the interior of the earth we live on.

A PIECE OF LAVA SHOWING PORES LEFT BY THE STEAM.

DIFFERENT KINDS OF VOLCANIC ROCKS.

If you could visit some of the volcanic regions of the United States, you would find rocks varying in appearance and containing different minerals. Some rocks are almost black, while others are light colored and you might mistake them for granite if you did not look closely. Some are compact and others are so full of holes that they do not look like rocks at all.

If you could examine a stream of lava that has become cold, you would find that at its center it is not as porous as upon the outside. The top sometimes appears like hardened froth. You have all seen the froth or foam upon the top of the water where it is much disturbed. The steam inclosed in the lava made it light and porous like the bread that has risen and is ready to bake.

Lava that has cooled very quickly is often glassy in appearance. We call such rock volcanic glass, or obsidian. It is sometimes almost as clear as common glass. At other times it is only translucent, or beautifully streaked like agate.

The Indians use obsidian for arrow and spear tips, and for knives. Obsidian breaks with a conchoidal fracture like glass and the fragments show very sharp edges.

A porous or froth-like obsidian forms the rock that we have called pumice. In the powdered form pumice is used for grinding and scouring. It is also placed in some kinds of soap, and forms the rough surface of sandpaper. Pumice, although heavier than water, will often float, because the holes in it are filled with air.

During volcanic eruptions, lava is frequently blown with great force high in the air. The heavier pieces fall down about the crater and build up a volcanic mountain. The pumice is so light that it is thrown farther, and the fine dust is carried by the winds for many miles over the land and sea. After volcanic eruptions in the East Indies sailors often report that their ships have been covered with a fine dust, although they may be hundreds of miles away from the point of eruption.

The fine dust-like particles thrown out of a volcano are usually called volcanic ashes. They are really not ashes at all, but fine particles of glassy lava or pumice. These particles of glass have sharp points

and edges, and as they are almost as hard as quartz, make excellent grinding material.

When lava cools slowly it does not form glass. Lava is composed of different substances, such as silica, alumina, potash, soda, magnesia, and iron, and when it cools slowly these unite to form the different minerals which we find in it.

These minerals are often large enough so that you can tell what they are. To the very dark lava we give the name of basalt. In this you may be able to see crystals of feldspar with their lustrous faces, and other crystals of a dark mineral, which we have called augite.

Lavas that are not so dark usually contain hornblende in the place of augite. Hornblende crystals in these rocks are usually black, with faces which strongly reflect the light. The fact that they are long and slender will aid you in distinguishing them from those of augite. Such a rock we call andesite.

To the light-colored lavas, in which you can find crystals of quartz, feldspar, and mica or hornblende, we give the name of rhyolite. There are many other kinds of volcanic rock, but you cannot distinguish them without a microscope.

Volcanic rocks do not have a granular structure like granite. The distinct crystals are scattered here and there as though shaken in with a pepper-box. The material in which the crystals lie is so fine-grained that you cannot tell much about it.

We have now learned that volcanic rocks differ in

character, depending upon whether they cooled fast or slowly, and also upon the proportion of the substances which compose them.

Igneous rocks sometimes become cold before they reach the surface of the earth. The erosive power of water may cause the removal of the overlying rocks, and thus expose the igneous rocks which appear as long, narrow dikes.

VEIN EXPOSED BY EROSION.

THE STORY OF A PIECE OF QUARTZ.

Here is a piece of glassy quartz. It is too large to have come from granite, for in that rock the grains of quartz are small. Our specimen is not a fragment of quartzite, for it is much clearer and more transparent than that rock, and besides it shows no traces of the little grains of which quartzite is composed.

This piece of quartz came from a vein in the mountains. Perhaps you do not know what a vein is. If you can imagine a great mass of rock with a crevice extending through it, which has been filled with a mineral of some kind, you will have an idea of the appearance of a vein. A vein, then, is an irregular

sheet of some mineral substance extending through the rocks. It may be from a fraction of an inch to many feet in thickness.

A vein may be formed of quartz or calcite or of several minerals together. Veins extend along the surface of the earth often for several thousand feet, and the deepest mines have not reached the bottom of some of them. Veins are interesting to us because it is from them that the most of our gold is obtained.

We have seen that the rocks are full of seams and fissures formed during disturbances of the crust of the earth. Many of our earthquakes result from the slipping of one portion of the rocky crust past another portion along one of these seams or fissures. The seams in the rocks also permit the water to pass through them.

You have all seen mineral springs the waters of which have a queer taste or disagreeable smell. Some of these are warm and others are cold. The waters of these springs come to the surface from points far below, passing up through the fissures of which we have spoken. The waters carry different mineral substances in solution and it is these substances which give them their peculiar taste or smell.

As the rain-water gradually sinks into the earth through innumerable little cracks some of it at last comes in contact with heated rocks. It is soon heated and as water in that condition dissolves many mineral substances much more easily than when cold, it takes out of the rocks some of the minerals that they con-

tain and carries them along in solution. Part of this hot water flows back toward the surface of the ground following the easiest path through the larger cracks.

As the water goes upward it becomes colder and begins to deposit some of the substances which it is carrying along the sides of the fissures through which it passes. If you will try the experiment you will find that you cannot dissolve as much salt in cold water as in hot.

If you have ever visited a mineral spring you will remember that there were strange looking deposits about the spot where the water came out of the ground. These are some of the substances carried in solution. Sometimes the fissures through which the water flows underground are several feet wide. If the water is carrying quartz in solution these cavities will be slowly filled by it. If the water should stop flowing before they were entirely filled we might find the sides lined with beautiful crystals of quartz sparkling like so many diamonds. Each little crystal has six sides and a pyramid with six faces at the end. The minute particles, or molecules, of quartz always arrange themselves in the same manner, so that whenever you find quartz crystals they will show the same shape.

A long time has passed since the most of our quartz veins were formed. Erosion has been constantly removing particles of the crumbling rocks from the surface and now these veins, because the quartz is very hard and indestructible, stand out plainly upon many mountain sides.

Quartz itself never decays, but the veins, like the rocks, have cracks running through them and so pieces of quartz tumble out and often reach the streams. It will take the water a long time to make smooth round pebbles out of angular pieces of quartz.

In some veins the quartz is as clear as glass. In others it is tinted different colors. Rose quartz is one of the beautiful kinds. Finest of all is the amethyst, with its clear purple or violet color. Then there is smoky quartz, and yellow quartz, sometimes called false topaz.

Clear glassy quartz is often called rock crystal. It is used instead of glass in making lenses for spectacles. You would hardly tell it from glass except by its greater hardness.

The ancients had strange ideas about glassy quartz. They called it crystal, supposing it to be ice frozen so hard that it could never melt. Beautiful vases and balls were carved from the clear crystal, and were greatly admired.

Quartz, or silica, as it is often called, is the chief constituent of common glass. It is first pulverized and then mixed with a little soda, potash, lime, and alumina. Then it is placed in a furnace and melted. The different kinds of glass are made by putting in different amounts of these various substances with the quartz.

If you can visit a glass manufactory you will be greatly interested in seeing the men blow the melted glass with their long tubes and shape it for different purposes.

ARAGONITE—WRONGLY CALLED ONYX.

SOME VARIETIES OF QUARTZ.

We shall now try to find out something about a number of those beautiful stones which when cut and polished are used for ornaments and jewelry. Many of these stones are varieties of quartz. They differ a little from common quartz in not being found in crystals with smooth faces and regular shapes, but in irregular forms. These varieties are also seldom clear and glassy, but colored various tints by small quantities of different minerals, such as iron and manganese. The different colors are often arranged in such a manner in these stones as to make them very beautiful and attractive.

We will speak first of chalcedony. Here is a smooth, light-colored stone which looks almost like a

waterworn pebble. Break it open and you will see that it has a soft, waxy luster. A part of it is almost as clear as quartz; another part is translucent, with a milky appearance. In many specimens you can see delicate, concentric bands of clear and cloudy, or milky, material.

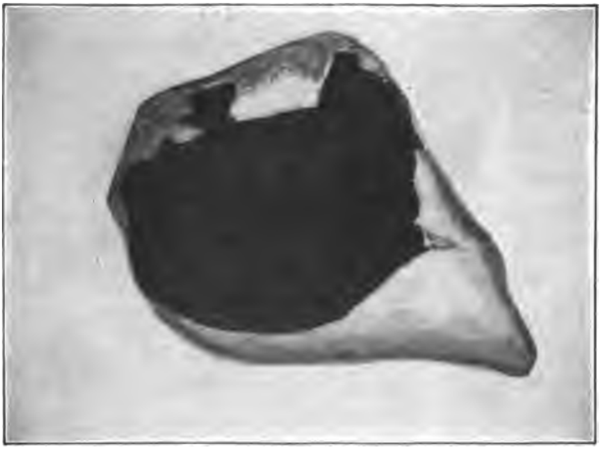
When the concentric bands become strongly marked, giving a succession of delicately contrasting colors, we call the stone an agate. You have all seen cut and polished agates. Upon the outside they appear rough and uninteresting, but within they are most beautiful, with the wavy or undulating layers of different color. The colors vary from white to brown, and almost black. A piece of polished agate is very attractive.

Agate and chalcedony have been formed in the same manner. We find them in the form of pebbles along some of the ocean or lake beaches, but this does not tell us anything about them. To find where they were made, we have to look among the rocks. They are more commonly found among the volcanic rocks. These often have cavities left by the gases that were in the melted lava.

After the lava cooled water commenced to creep through these rocks, as it does through all rocks that have open spaces in them. The water dissolved a little of the silica (another name for quartz) of the rock and, carrying it along slowly, deposited it in the cavities through which it passed.

Thus, beginning upon the outside, layer after layer

AGATE.



NODULE OF FLINT, FROM THE ENGLISH CHALK CLIFFS.

of the agate, or chalcedony, is formed until the center is reached and the cavity is full. The different colors of the successive layers are due to a little variation in the amount of iron, or manganese, which the waters carry in solution. If the waters are nearly free from coloring matter the bands are not distinct, and we call the deposit chalcedony.

If we break open a piece of lava we may find its cavities filled with the hard nodules of chalcedony or agate. When the rock decays these fall out and are washed away by the water. They are sorted out with pebbles of about the same size and left strewn over the beach where we find them.

Moss agate is another variety of quartz. In this the chalcedony, or quartz, is filled with delicately branched markings resembling moss. These are not of vegetable origin, however, but are due to impurities inclosed in the quartz.

Carnelian is different still. It has a reddish color. The tints are delicate and sometimes there are bands like agate.

Jasper is a variety of quartz which has been stained red, brown, yellow, or green by impurities, usually iron. Jasper is quite opaque, and has a dull luster.

Flint looks somewhat like chalcedony, but is much darker and more opaque. It breaks with smooth-curved surfaces. This kind of surface we call conchoidal because it resembles the curved surface of a shell. Flint is used by savages for arrow and spear points as well as for knives. You may have discov-

ered that flint breaks with sharp edges which will easily cut your fingers.

Opal differs from the other varieties of quartz by containing a little water and being amorphous. You will learn what is meant by amorphous in one of the later chapters.

Opal is the most beautiful of all the varieties of quartz. It is called a precious stone because of its beauty and consequent value in making jewelry. Opal is usually found in volcanic rocks and is formed in a manner quite similar to agate and chalcedony.

As the precious opal is turned in different positions you observe a succession of delicate iridescent colors. Can you tell what is meant by iridescent? The fire opal is seldom larger than a hazel nut, and is red or yellow with fire-like reflections.

The common opal is known under different names, such as milk opal, resin opal, jasper opal, etc. Opal is not quite as hard as common quartz.

A SECTION OF PETRIFIED TREE.

HOW WOOD CHANGES TO STONE.

Have you ever seen a piece of petrified wood? The word petrify means to change to stone. We often find pieces of stone which have the appearance of wood. There are the different layers just as they are found in wood. There is the bark also, and you may even find a knot.

Petrified wood has the structure and appearance of fresh wood, but it contains none of the substance of wood. The wood itself has disappeared, and in its place is something which has the weight and hardness of stone.

Let us find out now, if we can, how it is that wood can change to stone. There are several different minerals which are concerned in the process, but the

transformation is brought about in all cases through the action of water, which carries them in solution.

Lime and silica are the two substances which usually petrify wood. We will first study the effects of lime. Examine the inside of the tea-kettle and you will find there thin scales of a mineral we commonly call lime. To prove that it is lime, place a little weak acid upon it and you will see, by the immediate forming of little bubbles, that the acid has attacked it. The lime has slowly collected from the water that has been boiled in the kettle. At first the lime was dissolved in the water, and you could not see it, but the boiling of the water caused it to separate.

All spring water contains a little lime. Some springs carry so much lime that the water is not fit to drink. Such springs deposit lime about the spot where they come out of the ground and for some distance along the course of the water.

Pieces of wood which fall into this water will become petrified if they remain there long enough. The water carrying the lime in solution will penetrate all through the wood, and soon begin to deposit particles of the lime in the cells of the wood. After a time the cells will be filled and the woody fiber will be carried away and lime left in its place. At last, the organic matter forming the wood will be all gone and in its place will be a mass of solid mineral matter preserving perfectly the structure of the wood. The little cells, the layers of each year's growth, the knots, the bark, and every character of the wood may be

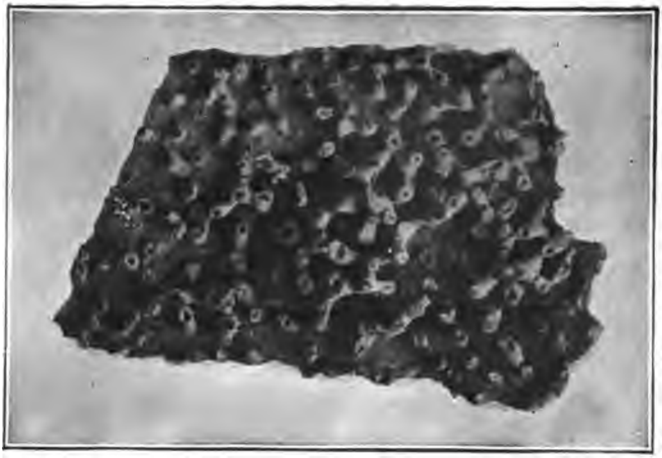
preserved so perfectly that you can tell what kind of tree the piece of wood belonged to.

Another mineral agent which causes wood to petrify under certain conditions is silica, or quartz, as you commonly call it. This mineral is dissolved in the waters of many springs, particularly those that are hot. In some of the mountains in the western part of the United States there are remains of forests which were petrified by the silica in the water where they were. Portions of tree trunks are sometimes found still upright, but the most of them have fallen.

The most wonderful petrified forest is in Arizona, where now the country is a desert. Tree trunks, which have been changed to beautiful agate, chalcedony, or amethyst, cover the ground. The trunks lie just as they fell long ages ago. They were buried during some disturbance of the region, and then water carrying silica dissolved in it flowed through the material in which the trees were buried. They were soaked with the mineral matter until changed to this beautiful stone.

Other substances beside wood will petrify if they fall into mineral waters. The more solid parts of animals, such as the bones, are often finely preserved.

Corals and shells that belonged to sea animals of long ago are often found inclosed in the rocks which were once sediments upon the sea bottom. These were originally formed of lime, but the lime has often been replaced by silica. We might call them petrified corals and shells.



LIMESTONE FILLED WITH CORAL STEMS.

HOW ANIMALS AND PLANTS HELPED MAKE THE ROCKS.

We have learned that a portion of the rocks of the earth's crust are of igneous origin. They were formed by fire. Another portion is of sedimentary origin. They were formed by water from the fragments of older rocks.

There are, besides these, some other very interesting ones which we now want to study. Water and fire are not the only agents that have been at work. Animals and plants have done their share toward changing the earth's surface and making rocks. It has not been upon the land, however, but beneath the water that this work has been done.

When land animals die their bodies decay, and at last even their bones crumble and, as dust, are blown

about by the wind. Plant stems also crumble, and what does not become mixed with the soil is also scattered far and wide. Thus you see that the bodies of living things cannot accumulate upon the land and form beds of any importance.

It is under the water that living things accomplish so much in building rocks. In marshes and swampy places plant remains are preserved by being covered with water. As a result of this we have the beds of coal which are so widely distributed over the earth.

If you will visit a swamp you will see that the stems and leaves of plants are slowly gathering. Under the proper conditions the bed which you see forming will, at some time in the future, make a seam of coal.

Peat is the first step in the formation of coal. In some parts of the world it is dug from swamps, and after being dried is used for fuel. It is simply a mass of decayed plants pressed together. The coal which we burn in our stoves is real rock just as much as sandstone or granite. It was formed from vegetation collected in swamps ever so long ago. The shining coal generally shows no traces of its plant origin, but once in a while we find upon it the impressions of delicate ferns and strangely marked stems.

It takes many years for the rotten tree trunks, branches, and leaves to collect in quantity sufficient to make a bed of coal ten feet thick. The original bed of vegetation must have been much more than ten feet thick.

ROCK FORMED OF SEA SHELLS.

The land on which we live, although it seems to us permanent, does not remain long at the same level. It is moving up or down, but generally very slowly. The swamps which existed so long ago were often upon sinking land. When the water became too deep the vegetation was killed and the currents of water sweeping across the marsh buried it under gravel, sand, and clay. In this way it was often covered by hundreds and thousands of feet of sediments.

The weight of those deposits pressed heavily upon the bed of rotten vegetation. This, together with the heat far down in the earth, changed it to a brown or black mass which crumbles in the air. This is the poorest coal and we call it lignite.

Those beds which were older and subjected to still greater heat and pressure were changed to bituminous coal and at last to anthracite coal. The latter is the purest of all, and is sometimes called stone coal because of its hardness.

Sea organisms that have hard skeletons have done the most in building rocks. The sea is filled with life. Along the shore we can see that the bottom is dotted with shells and seaweeds. Fish and other animals are moving here and there. In the tropical oceans corals are so abundant that their remains form whole islands. In addition to the animals that we can see there are infinite numbers of minute organisms. They are so small that you cannot tell much about them without a microscope. They are floating everywhere through the waters of the ocean. Their

bodies have a hard framework which is very interesting when viewed with a microscope.

As the fish, mollusks, corals, and these tiny organisms die their skeletons sink to the bottom and in the course of many long centuries form beds of great thickness. At last portions of the floor of the ocean

A BED OF FOSSIL OYSTER SHELLS.

are changed in such a way that the currents wash sands and clays over the bed of crumbling skeletons. They are buried deeply and finally compressed and changed into rock. We have already learned where the sands and clays come from and what part the waves and rivers have played in their accumulation.

If we could descend into the deep ocean we should find these animal bodies collecting there now as they have in the past. We should find them mingled in a soft, slimy mass called ooze. This ooze is found all over the floor of the deeper portions of the ocean.

Along the shore we find the shells of dead mollusks. In places the waves have washed them into a bed several inches thick. If we dig in the mud at low tide we shall find it filled with shells. After a long time this mud with the inclosed shells, as well as the bed of shells, may harden and form rock.

In the picture you see a mass of rock composed largely of shells. These lived in the ocean long ago. Some of them are as perfect as when the little animals occupied them.

Here in another picture is shown a piece of rock with coral seams in it. It is a portion of a coral reef built ever so long ago.

Those animals whose skeletons consist of lime have been the source of the beds of limestone abundant in many places. Those whose skeletons consist of silica have formed beds of flinty and jaspery rocks.

DIATOMACEOUS EARTH.

Diatomaceous earth is a soft white rock. It crumbles to powder in our fingers. It seems so light that we wonder if it will float upon water.

Diatomaceous earth looks somewhat like chalk, but it is made of quite a different substance. Although we can feel no grit in this soft rock, yet if we wet it and rub it gently upon a piece of stained silver it gives a fine polish.

We will place a little of the powdered rock upon a glass slide, drop some water upon it and then examine it under a microscope. What a pretty sight meets our eyes. Instead of little grains with nothing particularly interesting about them, we find the most curiously shaped figures. Some are round or elliptical, with rows of little dots which radiate from their centers. Others have the form of straight or curved rods. Many of the little forms are broken and with the dots over their surface appear like pieces of delicate lace.

These little grains, having such regular and beautiful shapes, are the skeletons of microscopic organisms called diatoms. A diatom is one of the lowest and simplest of the water plants. It belongs to a very large family known as algæ.

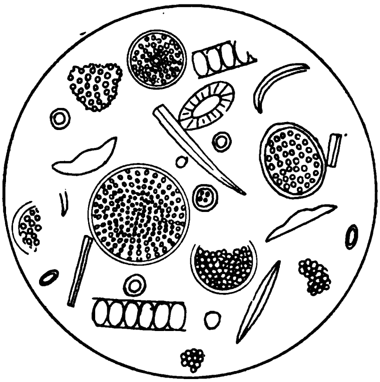
The diatoms are found in infinite numbers in both fresh and salt water. They sometimes form a yellow-

ish layer upon the bottom or are found adhering to sticks and stones. Some kinds float about in the water.

These organisms are particularly abundant in the ocean as well as in some lakes. Year after year their skeletons slowly accumulate upon the bottom, until at last beds many feet in thickness result.

Diatoms exist in nearly all parts of the ocean. Their remains help to form the soft deposits called ooze. The sediments from the land are carried only a few miles out into the ocean, and in the deeper portions of its bed far from the land the deposits are chiefly formed from the various organisms that inhabit those regions.

The skeletons of diatoms are formed of silica, which you know is another name for quartz. The kind of silica which we find in them is opal. The fineness of the material as well as its hardness makes it particularly useful as a polishing powder. The rock before being crushed is also used for filters because it is full of very small pores through which the water can pass slowly.



DIATOMS, MICROSCOPIC ENLARGEMENT.

LIMESTONE AND MARBLE.

Limestone and marble are very abundant rocks. In some places they form whole mountains. It is hard for us to realize that such thick beds have been formed entirely of the skeletons of animals, but yet it is true.

Different limestone beds were made by different animals, but all were inhabitants of the ocean. In one place we find cliffs of limestone dotted over with strangely shaped corals and shells different from any now living in the ocean. In another place we can find no large shells in the limestone, but instead the rock is filled with little round dots. These are skeletons of microscopic animals called foraminifera. This name means *full of pores*. The main portion of the body of the little animal was within the shell. It extended its numerous arms out through the pores of the shell. The arms aided in moving it about and in getting food. You can see the structure of the shell if you will make a thin slice of the rock and examine it with a microscope.

We can distinguish limestone from other rocks quite easily. If we put a few drops of acid upon a piece of limestone the acid will attack the lime and form little bubbles of carbonic acid gas upon its surface. Enough of the acid would entirely dissolve the

LIMESTONE QUARRY.

piece of limestone. Another aid in determining limestone is the fact that it is soft and easily scratched with a knife.

Limestone is of great value to us. One of its uses is in the construction of buildings. Its most important use, however, is in the manufacture of quicklime. The limestone is quarried and placed in a kiln. This is a low tower-shaped structure built of some stone which is not affected by fire. Wood is placed at the bottom of the kiln and the limestone on the top of it. The heat of the fire drives away the carbonic acid and leaves the limestone in the condition that we call quicklime, or simply lime. This substance is white and composed of calcium and oxygen and forms what we call an oxide.

This burned lime is used in making mortar. It has a great attraction for water, and when placed in it softens and becomes very hot. It unites with the water so actively as to create heat enough to make the water boil. It took heat to change the limestone into quicklime and drive off the carbonic acid. When water is added heat appears again without your adding any heat. Is not that interesting?

Quicklime, after it has been placed in water, is an active agent in destroying animal tissues. If you get much of it upon your fingers it will take the skin off and make them very sore.

Marble is the name we give to limestone that has been so changed by heat and pressure that it has become crystalline. Most limestone has a dull luster,

but marble shows the bright, glittering faces of the little grains of calcite. Calcite is only another name for lime, or rather for crystalline lime.

Common limestone is a hardened sedimentary deposit, as you have already learned; a deposit formed not of rock waste, but of animal remains. In its uncrystalline character we may compare it to shale and sandstone. Marble is metamorphosed limestone, as mica schist is metamorphosed shale, and quartzite is metamorphosed sandstone.

The metamorphosed sedimentary rocks are crystalline. We mean by this that they are composed of minerals formed by heat out of the fragmental material constituting the rocks in their original condition. In limestone you can often find shells and corals. When the limestone is changed to marble these are usually destroyed and you can then detect only the aggregate of bright calcite grains.

Marble is used in buildings more than limestone because of its greater beauty. It is found in many colors, white, gray, yellow, or composed of a variety of colors in streaks and patches. The variegated marbles are used in ornamentation, the white, fine-grained marble for statuary.

In countries where there are great beds of limestone many caves have been discovered. The rain-water soaking down through the earth and into the limestone beds dissolves the lime along its course and little by little forms caverns. These are sometimes of vast extent. You have all heard of the Mammoth

Cave in Kentucky. This was made by water, and you can follow it, with the aid of torches, for several miles.

There is an interesting variety of calcium carbonate, which we call chalk. You all know how this looks. It occurs in England as beds of soft rock. These beds appear along the coast and from their white color early attracted attention. If you could look at a bit of chalk under the microscope you will find it composed of the broken shells of little organisms, chiefly foraminifera.

STALACTITE OF CALCITE.

CLEAVAGE CRYSTAL OF CALCITE.

CALCITE AND DOLOMITE.

Quartz is the most common and widely distributed mineral. Next to quartz in abundance is calcite. In using the word calcite we usually refer to the crystalline calcium carbonate as it occurs in marble and in veins. Marble you already know something about. The calcite occurring in veins was deposited by water in fissures in the rocks. The kind of materials forming a vein in any place depends upon what the water contains. In one place silica is more abundant, in another lime.

When marble contains magnesium carbonate in addition to calcium carbonate we call it dolomite. By a carbonate of any substance we mean that the substance is combined with carbonic acid. We give the name dolomite to a mineral as well as a rock.

We call the mineral rock when it occurs in large masses.

Calcite and dolomite look much alike and often you cannot distinguish one from the other without a chemical test. Calcite will effervesce with weak hydrochloric acid; that is, little bubbles of carbonic acid gas will be formed where the acid touches it. Dolomite will not effervesce unless the acid be heated or the mineral powdered. Cleavage faces of dolomite show curved or wavy surfaces, the light not being reflected from the whole at once. Dolomite is a little harder than calcite.

Calcite occurs in crystals of many different shapes, but the most common is the rhombohedron, with diamond-shaped faces. Calcite exhibits perfect cleavage parallel to the faces of this crystal. If you take a rhombohedral crystal and strike it with a hammer it will break into smaller ones having a similar shape and bounded by similar smooth faces. This property of calcite, as well as many other minerals, is called cleavage. No matter what the size of the pieces of calcite their faces will always have the same position.

If we take a crystal of quartz and break it the pieces will be rough and irregular like those of broken glass.

Calcite is sometimes transparent and as clear as glass. This variety is called Iceland spar, because the best specimens have been found in Iceland.

Iceland spar has the property of affecting light in such a way that you can see a double image through

CALCITE CRYSTALS.

DOLOMITE.

it. Place a piece of the mineral upon a printed page and you will discover that every letter appears as two letters. Because of this action upon light Iceland spar is used in microscopes and other optical instruments.

Another variety of calcium carbonate is called aragonite. This mineral is found in veins deposited by water, and also in caves in the form of stalactites. Aragonite has the same composition as calcite, but a different crystal form. It does not show the cleavage of calcite and is a little harder.

Aragonite is usually marked by fine, wavy bands or layers. When cut and polished it makes beautiful ornamental material because of the different tints shown by the successive layers.

Aragonite has the appearance of onyx and is often erroneously called onyx. The latter mineral is a variety of quartz and you can very readily tell true onyx because of its much greater hardness.

Still another variety of calcium carbonate is to be found about the openings of some springs. This is called travertine.

Like aragonite, it is formed by more or less irregular deposition of the lime in the water giving rise to successive layers of different colors. These are white or red or brown, with intermediate tints, the colors being due to iron in the water. When cut and polished travertine makes a beautiful ornamental stone, being used for table-tops and decorative purposes. It is found in Eastern California and in Italy.

You can tell calcite from quartz because you cannot scratch quartz with a knife; it is not affected by acids and has a rough, vitreous fracture.

Calcite is distinguished from feldspar by its cleavage in three directions giving a rhombohedral crystal, while feldspar shows cleavage nearly at right angles. You can scratch calcite easily while feldspar is almost as hard as quartz. Feldspar is not affected by acids.

What an important mineral calcite is! In the form of limestone or marble it is burned for lime. Marble is used for buildings and for statuary. In a soft form, as chalk, it is useful in whitening walls and in making crayons, while the clear, crystallized variety is important in optical instruments. In soda water fountains it is the rock from which the carbonic acid gas is obtained, the gas which makes the drink so pleasant to the taste.

CLEAVAGE CRYSTAL OF ORTHOCLASE FELDSPAR.

A PETROLEUM SPRING.

THE STORY OF PETROLEUM.

Have you ever heard the story of petroleum, that clear liquid that fills our lamps?

Petroleum, or oil, as we sometimes call it, is a product of the rocks. Nature has not given it to us in the condition in which we are accustomed to see it, but as a brown or greenish liquid, sometimes almost as thick as tar.

Crude petroleum is treated to a long series of operations before it appears thin and clear like water. Almost everything that we get from the earth has to be refined before we can use it and petroleum is no exception. Some people think that petroleum came from land plants as our coal has. Some people believe that neither plants nor animals had anything

to do with it. Let us see now if we can find out the true story of petroleum.

Let us study the rocks that contain the crude oil and see what they are like. If we walk through some cañon in the oil regions we may find the rocks exposed. Here are some dark shales and limestones. We break a piece of either and hold it up to our noses; sure enough it has the smell of petroleum. The piece of rock is interesting, also, because it is filled with the remains of once living things. There are microscopic skeletons of diatoms and foraminifera that lived in an ocean long ago.

If we look at the rock closely we shall find that it is dotted with fish scales, and we may find, if we hunt long enough, the perfect skeleton of a little fish which has been buried for hundreds of thousands of years, a time so long that we cannot realize it. Occasionally you will find the bones of larger animals related to the seal or whale.

Little by little these animal remains accumulated in the ocean as generation after generation lived and died. At last they formed beds hundreds of feet thick. Changes came and these beds were buried deeply by deposits of different kinds, which pressed upon them so heavily that they were changed to stone.

Then came a time of earthquake movements. The bottom of portions of the ocean was lifted and the layers of rock were folded in great wrinkles, as you might wrinkle a piece of paper by pushing the opposite edges toward each other.

The pressure and folding made the rocks at the bottom warm, and chemical action began to take place. Chemical changes, you know, occur much more rapidly when there is heat than when it is cold.

If we should heat a piece of the shale or limestone already referred to and collect in a receiver what is driven off, we should obtain some gas and possibly a little petroleum. This gas will burn and is in many places collected from wells and used for fuel and for lighting houses. The process of driving these substances out of the rocks is called distillation. Nature distils oil and gas upon a great scale far below the surface of the earth.

The organic material, decayed animal bodies, from which the oil comes is scattered through the rocks, giving so little oil in any one place that if it had not been for the work of Nature distilling and collecting it we would not be able to make use of it. When the rocks became heated, chemical action began and the oil was forced out of the rocks, where it was originally, and collected in cracks and cavities or pores. The most of it gathered in porous rocks, such as sandstone, and there it remained stored for many, many years. In some places petroleum is still being formed and comes to the surface through springs and fissures.

It was many years after people came upon the earth before they discovered the value of petroleum. Attention was first called to it where there were springs. It collected in pools and people discovered that it would burn and had other useful properties.

SCENE IN THE LOS ANGELES OIL FIELDS.

Then men set to work to get more of it from the earth.

They studied the rocks where the oil came out and concluded that if wells were put down they could get it faster. Many were successful in tapping the reservoirs of oil hidden by Nature so deeply in the earth. Soon hundreds of derricks were erected and great quantities were obtained. People began to use it in their lamps instead of whale oil, which they had burned before.

Some of the wells have to be put down more than half a mile into the earth before they strike the oil-bearing rock. When a rich place is found the oil flows out in such a stream that it can scarcely be taken care of. Some wells produce hundreds of barrels in a day, but the most of them do not produce nearly so much.

In many oil fields the oil has to be pumped like water, but in others it flows out, being pushed up by gas. The crude oil varies much in appearance. It may be quite thin like water, or so thick and tar-like that it will hardly flow.

When thick oil penetrates sandstone it often forms what we call bituminous rock. This rock is black and sticky and although quite soft you can hardly break it. When the sun shines upon it the rock softens and melts down. Bituminous rock is used in all the large cities for paving streets. It is prepared by being melted in large kettles, and while soft and hot, is spread upon the surface and rolled smooth.

The thick oil which flows from the rocks in some places looks like tar. It forms great deposits upon the surface, and sometimes in the form of veins. When it becomes hard we call it asphaltum.

Crude petroleum is sent to a refinery either through pipes, or upon the cars. There it goes through different processes, until it comes out clear and thin like water. Many products are obtained in the refining of petroleum. Among these are gasolene, benzine, lubricating oils, paraffine, etc.

The animals that lived so long ago little thought that their bodies would furnish material of such great value.

COAL, GRAPHITE, DIAMOND.

Diamond is clear and sparkling. It is the most valuable gem, as well as the hardest mineral found upon the earth.

Coal is black and dirty, but nevertheless a very useful substance. It burns easily, giving off heat to warm our rooms, and run our steam engines.

Graphite is dark and has a greasy feel. It is not affected by any ordinary heat.

We are going to study these minerals together because they are made of the same element. We call this element carbon. Diamond and graphite are pure carbon, while coal has some impurities mixed with it.

Coal, you remember, has been formed from the remains of forests which long ago grew in extensive swamps. The vegetation was buried deeply and changed to coal by means of heat and pressure. The different stages in the formation of coal are shown first by peat, then by lignite, bituminous coal, and, last of all, anthracite. Lignite is the softest and most impure coal; anthracite, that which has been the most metamorphosed, and is composed of the purest carbon.

Charcoal is formed by burning wood out of contact with the air. This is nearly pure carbon. To prepare

charcoal, wood is cut and piled up and then covered with earth. A small opening is left for starting a fire, after which it is allowed to burn slowly for some time. The wood cannot be completely consumed because of the lack of air. You have all seen a piece of charcoal and can describe its appearance.

Soot is another form of carbon, which collects in stoves and chimneys because of the incomplete burning of the carbon in the coal or wood. When wood is completely burned, the carbon disappears as a gas, and there is left only the ashes. The ashes contain various minerals which were in the tissues of the wood. The ashes of coal also contain some impurities, such as clay, which became mixed with the vegetation in the ancient swamp where the coal was formed.

We think that graphite has been formed from coaly material in very ancient sedimentary rocks. When a bed of coal, with the inclosing shales or sandstones, is buried very deeply in the earth where the pressure and heat are great, all the materials are changed. The shales form mica schists; the sandstones are transformed into quartzites, and the coal becomes the mineral we call graphite.

Graphite is found in the oldest metamorphic rocks. It is a grayish or iron-black mineral, occurring as an aggregate of scaly particles, or in the massive form. Graphite is light and soft, and leaves a black streak upon paper, and has a slippery or greasy feel.

Graphite is also called plumbago, or black lead,

because it used to be thought that it contained some lead. You all know the most important use of graphite. In making pencils it is ground and mixed with clay and then pressed into slender rods. Graphite is valuable for crucibles. These are round, deep dishes in which metals are placed when we wish to melt them. Graphite, although related to coal, is not affected by the fire. Graphite has also other uses, such as lubricating machinery and blacking stoves.

The diamond is perfectly pure carbon. It is found in many parts of the earth, but the most of those now obtained come from South Africa. For a long time diamonds were only found in river gravels with such heavy metals as gold and platinum, and it was not known what kind of rock it was formed in. At the mines of South Africa it is obtained from dark, crumbling rocks which are supposed to be lavas cooled in the throat of an ancient volcano. Small diamonds have been formed artificially upon the sides of furnaces where there are gases containing carbon, and it is thought that those found in Nature were formed in a somewhat similar manner. The artificial product is known as carborundum, and is used as a grinding and polishing material.

The largest diamond ever discovered was about half as large as a hen's egg. In cutting and polishing, it was much reduced in size. Diamonds show different colors, but the clear ones are the most valuable. There are interesting histories connected with many of the large diamonds of the world.

The darker colored varieties of diamond are used for cutting and grinding rocks. Diamonds when set in the end of a drill, such as miners use, will cut a hole rapidly through the hardest rocks. The best glass-cutters contain a diamond, but the cheaper ones are made of hardened steel.

GRAPHITE.

THE DIFFERENCE BETWEEN MINERALS AND ROCKS.

We have been studying some of the minerals and rocks. Are we sure that we understand clearly the difference between a mineral and a rock? We will take a specimen of each and compare them.

Here is a piece of quartz and there one of granite. Now we say that quartz is a mineral. We call the piece of granite a rock.

There have been discovered about seventy elementary substances composing the earth. Only about twenty of these are abundant and of great importance to us. We call these substances elements because we cannot separate them into anything more simple.

Some minerals, such as gold, are formed of only one element. They are simple substances. Other minerals are composed of two or more elements combined. Quartz is composed of two elements. These are oxygen and silicon. Oxygen by itself is a gas and forms a part of the air which we breathe. The element silicon never occurs in Nature by itself, but always in combination with other elements. Oxygen and silicon are two of the most abundant elements.

Now the important thing for us to remember is that these two elements are not mixed in quartz as oxygen and nitrogen are in the air. We cannot make quartz

by taking a certain amount of each and mixing them. They are united chemically. If you mixed two substances mechanically each would still remain what it was before. When they unite chemically each one is changed, and together they make something entirely different from either.

When oxygen and silicon united to form quartz they did so in a certain proportion. This proportion is always the same, so that if you analyze a piece of quartz from any part of the world you will find that it contains the same amount of silicon and the same amount of oxygen.

A rock may be made of one or more minerals. You will remember that we found quartz, feldspar and mica in a piece of granite. Marble is composed of one mineral. The same is true of the rock we call quartzite. We call both marble and quartzite *rock* because they occur in such large bodies.

Most rocks are made of a mixture of two or more minerals, and these minerals are not always present in the same proportion. A piece of rock to which we give the name of granite may contain a little mica or a great deal. It will still be called granite, whether there be little quartz or whether quartz forms as much as one-half of the rock.

In granite, then, the components are minerals and are mixed or included mechanically and they may be present in almost any proportion. The mica is there as mica, the feldspar as feldspar, and the quartz as quartz. You see how different this is from the way

in which the components of quartz occur. They are always in the same proportion and you cannot separate them without destroying the quartz and getting substances exhibiting an entirely different character.

A mineral has always, when it is pure, the same weight and hardness. The weight of a rock may vary with the minerals composing it.

The crystals of quartz always have the same shape. The smooth faces or planes bounding them have the same relation to each other. The same is true of the crystals of feldspar, mica, hornblende, and every other mineral. A rock, on the contrary, has no crystal form. It is made of minerals which, as we have seen, have their own peculiar forms.

We can make many minerals and rocks in the laboratory under the proper conditions. If we put in a crucible a certain amount of quartz, lime, alumina, magnesia, iron, potash, and soda, we can melt these all together into a fiery fluid. If we place this where it will cool very slowly we shall get a rock containing crystals of feldspar, mica, hornblende, quartz, and perhaps other minerals.

What minerals appear in the rock will depend upon the proportion of the different substances melted together. If there was but little quartz put in we would find no quartz in our rock for it would all be needed in the making of the other minerals. Each one of them contains quartz combined with other substances.

THE DIFFERENCE BETWEEN MINERALS AND METALS.

We have learned that a mineral is an inorganic substance with a definite composition and certain physical characters which it always exhibits. A piece of rock, or glass, or crockery has not a definite composition. Each of these things is made of several elements, but one or more of these elements can vary in amount without greatly altering the nature of the rock, or glass, or crockery.

We have learned further that a mineral may be made of one or more elements or simple substances of which there are about seventy forming our earth. Some minerals contain nearly or quite a dozen elements.

We divide minerals into two classes. In one class are included those that we call metals, in the other the non-metals, or simply minerals. Why do we say that gold is a metal and mica a mineral? What is meant by these terms?

We might say that, in general, a metal is one of those minerals formed of only one element. It is a simple substance. Gold is a good example of a metal. We might say further that all minerals belonging to the class of metals have a peculiar shining appearance or luster, as we have called it, which is termed metallic. We say that tin has a metallic luster.

The metals can be drawn out into wire or hammered into any shape that we wish. They are good conductors of heat and electricity. Gold, silver, copper, iron, tin, and lead are good examples of the metals. Most metals have a high specific gravity; that is, they are very heavy.

Our definition of a metal as a simple substance having a certain kind of luster as well as other properties, is not quite true in all cases. Carbon and sulphur do not have the characters of metals as far as luster, malleability, etc., are concerned.

Among the minerals which are not metallic we will mention quartz, feldspar, hornblende, salt, borax, etc. Some of the minerals, such as biotite mica, have a luster, which is almost metallic. We call it submetallic. Mica does not resemble the metals in any other respect.

After you have become a little familiar with minerals you will have no trouble in distinguishing the metals. The peculiar shining luster of metals you will not forget when once you have had your attention called to it.

HOW MINERALS DIFFER FROM PLANTS AND ANIMALS.

We can divide everything that we have ever seen into two kinds. First, that which is alive or is the product of life, and second, that which has no life. In the first we include animals and plants. In the second are the rocks and minerals. The animals and plants belong to the organic kingdom, for they have different organs to carry on life. The inorganic or mineral kingdom includes all those substances without organs.

In an earlier chapter you learned that our earth was once a fiery ball. At that time nothing could live upon it. There were even no solid rocks. Minerals could not exist, for at that temperature the elements were not combined with each other. At last the first rocks were formed and after a long time low forms of plants and animals appeared.

Animals and plants are born, grow up, and finally die. Animals have organs for various purposes. They eat food, they breathe, and the most of them move from one place to another. Plants are simpler than most animals, and yet they have organs for various purposes. Nearly all the plants remain fastened in one place the whole of their lives.

Minerals exhibit a very different nature. They

have no organs and show no life. The mineral does not grow by the assimilation of food, but by simple additions upon the outside. We take a mineral and break it in pieces. Each piece is just as much a mineral as was the whole. Each of the organs of a plant or animal is for a special purpose. If we cut a plant in pieces we have destroyed the plant. One piece cannot live without the others.

The plants and animals that first appeared upon the earth were very simple in structure. Many similar to them are living at the present time. They have no head, no blood, no distinct stomach; the whole body acts as a stomach.

Simple organisms have been found that seemed intermediate between plants and animals. Some substances have been found with so simple a structure that it is hard to say whether they belong in the mineral kingdom or the kingdom of life, but in general, as you can readily understand, the two kingdoms are not at all alike.

We think that rocks and minerals never change, but many of them do. We have already seen how granite crumbles, and the hard feldspar grains soften and become clay. Many of the minerals seem to be thirsty. They take in water until they are quite changed. Other minerals, such as quartz, do not change as far as we can see.

Living things have to depend, in the first place, upon things without life. The plant gets its food from the soil and air. It builds into its framework

some of the minerals, such as silica, soda, and potash.

Animals draw their nourishment from the plants or from each other. Their bones contain lime. Iron is found in the blood. A portion of these minerals is drawn from the water, another portion from the solid food.

You will have little difficulty in telling whether a thing is the product of life, or whether it belongs to the mineral kingdom.

A BIT OF CHEMISTRY—CHEMICAL ACTION.

Changes are continually taking place in substances around us.

If you leave a piece of iron unprotected it soon becomes covered with a brownish coating. After a time the iron will have entirely disappeared, and this brown coating, or rust, as we call it, will have taken its place.

A piece of coal is burning in the grate. It soon disappears and there is left only a small pile of ashes. Animal bodies and trunks of trees decay, and after a time are gone. The rocks decay, and the minerals forming them change their appearance.

The original substances with which we are familiar lose their physical properties so that we can no longer recognize them. New substances are formed in their place with entirely different characters. Changes such as we have described are called chemical changes. If you break a piece of rock into fragments you have made no chemical change; you have altered its physical appearance only. It is as much a rock after being broken as it was before.

Chemical changes either require or produce heat. We feel the heat given off by burning coal, but the decay of wood or the rusting of iron, which is really a burning of those substances, takes place so slowly that we are not aware of the heat given out.

To further illustrate a chemical change we might take some fine copper filings and mix them with sulphur. If we heat this powder it becomes red hot quite suddenly. Upon cooling it, the two distinct substances will be found to have disappeared and a new one to have taken their place. This new substance is a black powder, quite different from anything we had to start with. By treating it in a certain way we can recover the original substances.

It is believed that long ago the earth was so hot that everything existed in a gaseous condition. We can easily change many of the liquids and solids with which we are familiar into a gaseous condition. Some become gaseous with great difficulty.

When all the elements of which our earth is composed were in a gaseous state, they were too hot to have any attraction for each other, and existed without combining. Oxygen was not combined with silicon to form quartz, but each existed independently.

As the earth began to cool, the elements united with each other to form the mineral and gaseous compounds that we find to-day. In forming minerals the elements acted as though they had their friends and enemies. Certain ones seemed to draw one another and to repel others. This used to be called chemical affinity. You can, perhaps, understand this better by thinking of your own likes and dislikes. You are drawn to certain of your playmates and are happy in

their company. There are others that you do not care to associate with.

Oxygen gas does not seem to have much interest in gold, but it is very strongly drawn to carbon and silicon. With silicon, it forms the most common mineral — quartz. Oxygen is an energetic agent and has united with almost all the other elements.

Many of the elements have such a strong attraction for each other that it is difficult for us to take them apart. When water is analyzed, we get from it two gases — oxygen and hydrogen. If we mix these gases in a bottle, and place a lighted match at its mouth, the two gases will go together so violently as to cause an explosion.

We all know how powder behaves when a lighted match is touched to it. Powder is composed of a mixture of sulphur, saltpeter, and charcoal, and it only takes a little fire to make them unite violently. If we mix nitric acid and glycerine we get a compound called nitro-glycerine. This is a dangerous substance, and sometimes a little jar will explode it.

Chemical changes are taking place all about us, yet we are not aware of the most of them. We could not get nourishment from our food if it were not for chemical changes that take place in it. The growing plant, with the aid of the sun, produces such changes in the substances which it takes from the soil that they can be transformed into animal tissue.

Chemical changes in rocks and minerals are constantly going on, but the transformations are mostly

slow and quiet. Few things remain permanently in one condition.

When man takes hold of the substances forming the earth, and adapts them to his use, he causes many of the changes to go on more rapidly. He interferes with Nature in many ways. Sometimes he does not manage these chemical changes carefully and suffers for it. He should take good account of Nature's laws.

THE WORK OF OXYGEN.

In studying our earth we meet with some strange facts. One of these is that the most abundant and widely distributed substance is a gas. This substance is necessary to the support of all living things. It is invisible, odorless, and tasteless. I am sure you know of what I am speaking. It is oxygen, without which we could live but a few moments.

Oxygen is an element and is found in the air uncombined with anything else. It forms one fifth, by volume, of the air. The other important constituent of the air is nitrogen, the oxygen being simply mixed with it.

Combined with other elements oxygen forms about one third of the solid crust of the earth. It is also one of the components of water.

Oxygen is the most active of the elements. It unites with all the other elements except two. It attacks different compounds and destroys them. At a low temperature it does its work slowly. It takes years for a log of wood to decay and crumble to dust. When oxygen is working rapidly it forms a great heat and we say there is a fire. With the aid of a little heat to start with, oxygen will destroy a pile of wood in a few moments.

We say that fire burns better when there is a

draught. By this we mean that it burns better when there is more air, and consequently more oxygen. If you wish your fire to go down you close up the openings through which the air can get to it.

Take a jar and invert it over a candle. In a few moments the candle will burn fainter and finally go out. The flame will last only as long as there is oxygen to support it.

A piece of iron exposed to the weather is slowly attacked by oxygen and a coating of oxide of iron, or rust, as we commonly call it, is formed over the surface. We say, however, that iron will not burn in the air. The oxygen does not destroy it fast enough to produce any noticeable heat.

Iron will burn rapidly in pure oxygen. Take a fine steel spring and after heating it to take out the elasticity, fasten to the end something which will burn readily and then place it in a jar of oxygen gas. Light the substance at the end of the spring and the iron will take fire and burn with a bright light. Glowing drops of iron will fall from the burning part to the bottom of the jar.

We have to protect many of the materials that we use so that oxygen will not destroy them. It works more rapidly in the presence of water. Consequently we paint our wooden buildings to keep the water away from them. We cover our iron implements with paint or polish of some sort.

Oxygen is necessary not only for land animals, but for those in the water also. We take air into our

lungs. From the lungs it goes into the blood and to every part of the body. The oxygen unites in slow combustion with the food which we eat producing heat and energy. If we should breathe air containing pure oxygen it would destroy our tissues. The nitrogen mixed with the oxygen of the air makes it less active. If we breathe air containing too little oxygen we become weak and languid. Men who work underground must have fresh air pumped down to them to enable them to remain there. In some mines the air becomes warm because the oxygen attacks and combines with some of the minerals that the miners uncover.

We now see how destructive an agent oxygen is. It is at work constantly upon nearly all substances that it can reach. It even destroys the minerals and rocks, making new minerals out of them.

An animal, as long as it is alive, needs oxygen to continue its life. When it dies, oxygen goes to work immediately tearing the body to pieces; destroying what it before helped build up, and making new substances which are more permanent.

CARBON, NITROGEN, AND HYDROGEN.

We have already studied the different forms in which carbon appears. No other element presents such diverse characters as carbon does in the three minerals — coal, graphite, and diamond.

All substances that have life, or are the product of life, contain carbon. It forms the essential part of coal, and is one of the constituents of petroleum.

Carbonic acid, combined with calcium, appears as extensive beds of limestone, marble, and chalk. It is also found in small quantities in the air, as well as in water.

Charcoal and lampblack are forms of carbon produced artificially, and are of great value in the arts. You can obtain lampblack by holding something that will not burn in the flame of a lamp or a gas-jet. The sooty deposit which soon appears is very pure carbon. It is used in the manufacture of ink, and forms the pencils in arc lamps.

Carbon dioxide or, as it is commonly called, carbonic acid, consists of carbon and oxygen. It is formed whenever any compound containing carbon is burned. This is an invisible gas, having a very faint odor.

Carbonic acid dissolves easily in water and gives to it a pleasant, pungent taste. Soda water contains no

soda, but carbonic acid instead. The bubbles which rise from a glass of soda water are carbonic acid gas. You have all seen a bottle of soda water opened, and have noticed the little bubbles of gas appear as soon as the cork is taken out and the pressure is relieved. The pressure holds the gas dissolved in the water.

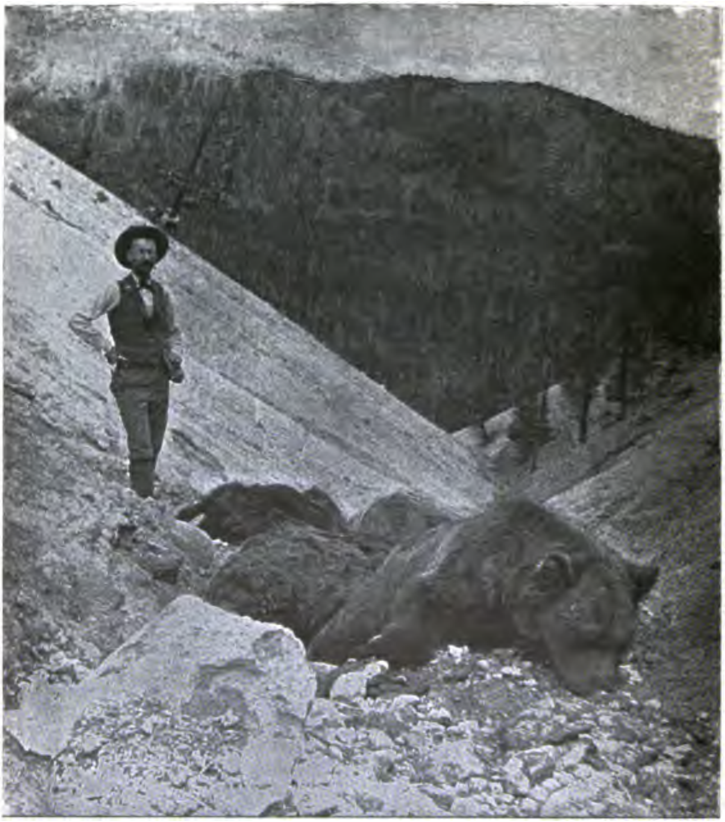
Carbonic acid is formed when the bodies of animals and plants decay. We give it off also in breathing. You might think that the air would become so filled with carbonic acid as to be unhealthful, but it does not. The leaves of plants absorb a great deal of it, building the carbon into their tissues.

The gas which you see coming out of many mineral springs is carbonic acid. We call such springs soda springs. Birds, and even animals as large as bears, that go to these springs to drink are often overcome by the gas and die before they can get away. Carbonic acid gas is abundant in coal mines, and adds greatly to the danger of working there.

Nitrogen is almost the opposite of oxygen. It is inert and indifferent to other substances. Oxygen is active and aggressive, attacking almost everything. If we burn the oxygen out of the air contained in a jar, what remains is mostly nitrogen. Nitrogen forms four fifths of the volume of the air.

Nitrogen and oxygen are mixed mechanically in the air. Each one is there with its own properties. In water, hydrogen and oxygen are combined chemically.

Nitrogen dilutes the oxygen of the air so that we can breathe it. Nitrogen is not poisonous, but ani-



LOOKING DOWN THE GULCH—THE LATEST VICTIM, A LARGE SILVER-TIP GRIZZLY.

From *Popular Science Monthly*. Copyright, 1899, by D. Appleton & Co.

mals cannot live in it. Nitrogen occurs in the tissues of plants and animals, and in the products formed by their decomposition.

Another gas that we want to know something about is hydrogen. This gas, as we have already learned, is one of the components of water. If we take some hydrogen gas and mix it with oxygen gas in a jar, and then place a lighted match in the jar, they will instantly unite. An explosion takes place, and in the jar where the gases were we shall find a few drops of water. The water occupies much less space than did the two gases. Water is an oxide of hydrogen, as quartz is an oxide of silicon.

Hydrogen is the lightest of all known substances. For this reason it is used to fill balloons. The gas being so much lighter than the air, it tends to rise, and will carry up a considerable weight.

GASES, LIQUIDS, AND SOLIDS.

Whether a substance is a gas, a liquid, or a solid, depends upon temperature and pressure. If we lower the temperature of water it becomes solid. We say that it freezes. If we take oxygen gas and place it under great pressure and keep it cold we can change it to a liquid.

It is thought that a long time ago when the earth was very hot, that all the substances now in the liquid and solid condition, were gases.

Now let us find out some of the properties of substances in the three conditions, solid, liquid, and gaseous. We say that a thing is a solid if it retains its shape. A block of wood keeps the same shape as long as it is wood. The particles of which it is composed are so firmly attached to each other that they cannot change their position.

Some solids are malleable and elastic. We can alter their shape by hammering them, and if they are elastic they will spring back when bent. Other substances are brittle. Their particles are attached to each other in such a manner that a blow will break them apart.

In the case of a liquid the particles are free to change their position with reference to each other. Put your finger in a dish of water and the particles

move aside and make room for it, making but slight resistance. A liquid takes the shape of the dish in which it is held. A liquid can be poured. It breaks up into drops if poured slowly. Upon an inclined surface the drops will unite and form a little stream. The stream, because of the pull of the earth, or the force of gravity as we usually call it, seeks the lowest place it can find. A liquid will remain at rest only when it is inclosed by something as high as itself. Then gravity cannot affect it. What ruin has been wrought by the breaking of a dam!

A substance when in the gaseous state occupies much more space than when liquid or solid. Particles of matter in a gaseous state are generally invisible. We can smell many of the gases and feel them when they are forced against us. The air in motion is an example of this.

Gases are very elastic substances. The particles of which they are composed act as if they repelled each other. They will spread indefinitely through the air unless confined. When we try to make a gas occupy smaller space it resists and very strong vessels are needed to hold it. Engine boilers are carefully made so that the steam cannot break them and cause an explosion. By keeping the steam in the boiler under pressure we make it do a great deal of work for us.

If our earth should become much colder some of the present gases might become liquids, and the liquids solids.

Nearly all minerals are solids, but we must not

think that they are necessarily so. Water is a liquid with a definite composition. It is to be considered a mineral body just as much as ice.

We look upon quicksilver as a mineral, although it has all the properties of a liquid. If we place quicksilver in a very cold place it will become solid.

Lead is a mineral easily changed by heat to the form of a liquid. If we heat it still more it volatilizes, that is, it becomes a gas. Quicksilver and sulphur do not need a very great heat to become gases.

WAYS IN WHICH MINERALS ARE FORMED.

There are several different ways in which minerals are formed. Would you not like to know about them?

We will first take a cup of water, and put in it all the salt that will dissolve. We now have a solution of salt which we say is saturated; that is, the water will take up no more of the salt.

Place the salt water outside when the air is dry, and pretty soon, as the water begins to evaporate, you will see the little crystals of salt forming all around the sides of the dish. When the water has all gone into the air the salt, which was dissolved in it, will be found in the form of a mass of cubical crystals lining the sides of the dish. In this manner such minerals as soda, borax, and rock salt are formed. They were dissolved in the water of ponds or lakes, and when the water dried up were left, mixed with more or less mud, on the bottom.

Other minerals that we shall study, like calcite, dolomite, iron pyrites, and gold, for example, were dissolved in water deep in the earth. This water was often hot, and in that condition would more easily dissolve minerals. Many minerals can not be dissolved in pure water, even if it is hot, but if a certain other mineral is present in the water they will be

taken into solution. As the water flowed toward the surface it became cooler, and the pressure upon it less, until the minerals which it carried began to be deposited. In this manner veins of quartz, calcite, gypsum, and many other substances, were formed.

Several minerals rose toward the surface in the form of vapor or gas, and upon getting where it was cool, were condensed upon the walls of the fissures through which they were passing. Take a little sulphur and place it in a glass tube closed at one end. Heat the sulphur over the flame of a lamp, and it will soon begin to change to a brownish-yellow vapor. The vapor rises in the tube, and upon reaching a cool portion is condensed upon the sides. You can see it as little yellow specks.

Many of our minerals have been formed in still another way. They crystallized out from a hot, fiery liquid where all were mixed together. As the liquid cooled, crystals started and continued growing as long as each could get the molecules of matter that belonged to it.

Most rocks contain silica, lime, alumina, magnesia, iron, potash, soda, and small quantities of rarer minerals. If we take several pieces of rock of different kinds, pulverize them, and place them in a crucible in a very hot furnace, they will at last melt together in one glowing mass.

When this liquid begins to cool, the different elements will group themselves according to their attractions, or likes and dislikes, as we might call it.

Molecules of feldspar will form and attract others, and so continue to grow in size. Molecules of hornblende will do the same, and so with every mineral. The condition, however, which we must fulfil, is that the liquid shall cool very slowly. If it cools rapidly there will be formed a glass like volcanic glass. The particles of matter will not have time to group themselves according to their attractions.

We have now found that minerals may be formed in one of three ways; namely, by crystallization from solution, by condensation from vapor, and from igneous fusion.

ACIDS, ALKALIES, AND SALTS.

What do we mean by an acid, an alkali, or a salt? We use these words quite often in speaking of the substances about us.

First, what is an acid? We have all tasted sour things. Some apples are very sour. Vinegar is sour. Those substances which have a sour taste we call acids.

Acids will dissolve many substances that water will not affect. Some of them are very powerful and will burn deeply if they come in contact with your skin.

The acids which the most of us have to do with are those found in fruits. Vinegar contains acetic acid. It is prepared from different substances, but that obtained from apple cider is the best. Citric acid is found most abundantly in the juice of lemons, gooseberries, etc. Oxalic acid occurs in sorrel and rhubarb. When taken in a large quantity it is a deadly poison.

To determine if any liquid that we are experimenting with contains an acid we test it with a piece of litmus paper. This is a paper stained with a dye obtained from the juice of certain lichens. The paper has a blue color and if placed in an acid it will turn red. This is one of the best tests for an acid.

Acids are of great importance in the laboratory. Diluted hydrochloric acid placed upon a mineral will

tell whether or not it is a carbonate. Take a piece of limestone, or marble, and drop a little of this acid upon it and the surface will immediately be covered with bubbles. The limestone will be destroyed if there is enough acid, and the acid itself neutralized with the formation of a new substance.

Hydrochloric acid is made from common sea salt. The acid is a gas, but it is passed into water, where it is absorbed. This permits us to use it in the liquid form, which is much more convenient.

Nitric acid is made from saltpeter which is obtained from the surface of some of the deserts of South America. Saltpeter is soluble in water, so that we cannot expect to find it in regions where it rains much.

Sulphuric is another one of the acids which we have to handle in a very careful manner. It has great corrosive power and will destroy your clothes or skin very quickly. It is sometimes called oil of vitriol. It is obtained from the sulphurous gases produced in the roasting of iron pyrites.

The alkalies are the opposite of the acids. They destroy the sour taste of acids when mixed with them. If you will take a little hydrochloric acid and pour into the dish with it some ammonia water, which is alkaline, you will obtain a liquid which is neither an acid or an alkali.

Caustic soda and caustic potash are the common alkalies. The term caustic is given to them because they destroy or burn your flesh. Caustic soda was

first prepared from wood ashes by soaking them in water and then evaporating the water. You can easily find out for yourself how much soda ashes contain by performing this simple operation.

A liquid which is alkaline will change reddened litmus paper back to blue.

There is a class of substances which will neutralize acids, as we have already seen. These substances are called bases. If we add some nitric acid to a solution of caustic potash the alkali and acid will each lose its properties and there will remain something entirely different. Evaporate the liquid and you will find in the bottom of the dish a white crystalline substance. This is potassium nitrate, or saltpeter. To this class of substances, for there are many of them, is given the name of salt.

Our common salt was one of the first known of these substances and the name was given to the whole class of such substances because of their resemblance to this salt.

A salt then is formed by the combination of an acid and a base. Let us mention a few of the salts: saltpeter, epsom salts, sal ammoniac, common salt.

THE MOST VALUABLE MINERAL — GOLD.

You have already learned the difference between metals and minerals. You have learned that we give the name of metal to those mineral substances which are formed of one element and have a peculiar shining luster.

We sometimes use another term for the metals. We speak of native gold, or native copper, meaning by this that these mineral substances occur in Nature pure: that is, uncombined with other substances.

We call gold one of the most valuable minerals. Still, do you not think we could get along without it easier than we could without iron? We prize gold so much partly because of its beauty and partly because of its rarity.

Gold is a soft, bright yellow metal. It can be drawn out into fine wire and hammered into exceedingly thin sheets. It does not tarnish in the air, and is in every way adapted for use as ornaments. Because of its softness gold usually has a little copper mixed with it to make it harder and wear longer. This is true of its use in jewelry and in our coins.

As Nature made up the world and arranged the rocks and minerals she often put the most beautiful

things and those which seem most precious in places where they are hard to get. Because of the value of gold, men will go to the most distant parts of the earth, spending years and suffering all kinds of hardship to get it. Gold is found in most mountainous regions, especially in those where there have been many disturbances of the crust of the earth and the formation of igneous rocks. The discovery of gold was one of the chief reasons for the rapid settling of the Rocky Mountain and Pacific Coast states.

Gold has generally been left by Nature in veins of quartz which extend through different kinds of rocks and outcrop along the surface. We believe that long ago there were many warm mineral springs where now we find the veins of quartz. In some places there are springs of this kind at the present time depositing minerals and making veins.

The waters of the ancient springs carried many minerals in solution. These minerals were dissolved out of the rocks thousands of feet, and perhaps miles, below the surface. We do not know but that away down in the earth there are greater quantities of the metals than near the surface. Men have weighed the earth and found that it is much heavier than it would be if formed mostly of rocks with which we are familiar. The metals are in most cases, you know, heavier than the minerals forming the rocks.

The mineral springs which we find still flowing, help us to understand how the veins were formed, and the precious metals left in them. As the heated

waters from far below were forced up through the cracks in the rocks, they deposited some of the substances that they were carrying. Gold and iron pyrites and other minerals were left mixed with the quartz. Now we find little grains and threads of the yellow metal scattered through the solid quartz. We sometimes wonder how it got there.

A GOLD MINE IN THE DESERT.

The gold that we can see in the quartz we call free gold. Where the gold is free it is quite a simple matter to obtain it. The pieces of quartz as they come from the mine, are dumped into large bins. From these they are fed under a row of heavy iron stamps. Each of these often weighs nearly half a ton.

The stamps rise and fall and slowly pound the quartz to a fine sand. As fast as the quartz is ground the sand and grains of gold are washed away by a little stream of water and carried over broad copper plates coated with quicksilver. This latter metal has an attraction for gold, catching and holding the little particles while the crushed quartz is carried away by the water. The mixture of gold and quicksilver is called amalgam. It looks more like quicksilver than it does like gold, although the quicksilver is no longer liquid. The amalgam is scraped from the plates and heated in a furnace, and the quicksilver being very volatile, is carried away in a gaseous condition while the gold is left pure in the crucible.

Sometimes the gold in the quartz veins is not free, but is combined with other minerals. In most quartz veins there are large quantities of iron pyrites which often contain gold. To get the gold from the pyrites the rock is crushed as before and the heavy pyrites separated by machinery.

The pyrites is then taken to a furnace and roasted in a hot fire. The heat drives away the sulphur of the pyrites and leaves the iron and gold. Now the gold is dissolved by a poisonous suffocating gas called chlorine. This unites with the gold to form a new substance called chloride of gold. From this compound the gold is recovered in the metallic state.

Mines have been opened more than half a mile into the earth in search of gold. The quartz veins which

outcrop upon the surface have been followed down and down without coming to the end of them. Upon the sides of the veins there are often found seams of clay and broken rock, showing that they occupy fissures whose walls have moved and ground upon each other.

MINERS PROSPECTING FOR GOLD.

PLACER MINING.

In the previous lesson we learned about the gold obtained directly from quartz veins. Not all the gold that we use has been obtained in this manner. A large part of it came from gravels in the beds of streams. Digging for gold in gravels we call placer mining. The gravels themselves are called placers.

How the gold became mingled with the gravels is a story in itself. I am sure that you have noticed that during every heavy rain the surface of the ground is being washed away. The soil, the gravel, and sometimes larger pieces of rock, are borne into the creeks and rivers by the force of the little torrents. You cannot go out into the country anywhere without seeing the gullies which have been washed out by the water at some time.

You have already heard how the rocks are decaying and crumbling under the action of the air, the moisture, the heat, and cold. As a result of this decay, soil and rock fragments cover much of the surface. As the surface wears away in a region where there are quartz veins carrying gold, these veins also break into fragments. Much of the gold, freed from the quartz, is mixed with the broken rock and soil. In company with this waste the gold is washed into the streams, but being so heavy the water cannot move the gold as

HYDRAULIC MINING.

readily as it can the rock fragments. The gold gathers upon the bed-rock at the bottom of the stream, moving slowly down the stream when the current is swift, or lodging in the hollows of the rock.

The most of the rock waste is carried by the stream farther down. The quartz fragments are rounded to pebbles, and the softer fragments ground to sand and clay. Much of this material eventually reaches the ocean.

Year after year, as the rocks slowly crumble, the gold continues to collect in the stream gravels. This is going on to-day just as it has been for thousands of years.

The gold first discovered in California was in the gravels of the streams. Men soon began to flock from all parts of the world to share in the wealth of the streams flowing from the Sierra Nevada Mountains. When the gold in the present stream beds had been worked out it was discovered that there were channels of streams of long ago, high up on the hills, that were also full of gold.

In placer mining the prospector takes a pan and shovel and explores along the creeks. He digs holes here and there down to the bed-rock. This is the solid rock beneath the gravels. After taking some gravel from the bottom of the hole he places it in a pan of water, and washing it around with a peculiar motion, gets rid of the sand and pebbles. In the bottom there will remain any heavy substances that were mixed with the gravels, such as iron and gold.

When the miner discovers enough gold to pay, he builds a sluice, which is a long box, or trough, of boards. Into this a stream of water is turned, and after digging a trench to reach the richer gravels at the bottom he shovels them into the sluice. The water washes the gravel through, and the gold is caught by little cross pieces, called riffles, nailed upon the bottom.

GOLD NUGGETS.

In the ancient stream beds the gold is often buried a hundred feet or more by gravels and boulders. Getting gold from such stream beds is called hydraulic mining because the gravels are torn down and washed into the sluices by the powerful force of a stream of water conducted to the place in pipes.

These old stream gravels are on the tops of the

hills, and to get water to them it has to be brought many miles in ditches and flumes. Before reaching the mine the water is collected in a reservoir, and from this it is led down in pipes to the gravels. The water thus acquires great force and is directed against the bank of gravel. It washes the bank down rapidly, even moving large boulders. Sometimes pieces of gold called nuggets, of many pounds weight, are found in the gravels.

There are other interesting things besides gold washed out of these old stream beds. There are pieces of petrified wood derived from trees, which lived long ago, when these gravels were in the bed of a stream. Occasionally the bones of animals are uncovered. They belong to animals unlike any living to-day.

THE MOST USEFUL MINERAL—IRON.

I think that if you should ask any one what mineral is of the most use to us he would say that it is iron. It would take you a long time to mention the common uses of iron. If all the iron should be removed, we would be almost helpless, because so many of our implements and dishes are made of it.

We feel grateful to Mother Nature that she has put so much iron into our earth. No other mineral, which is abundant, possesses so many valuable properties as iron. It is adapted to a great variety of uses.

Iron occurs as a constituent of all rocks. It is iron which gives the reddish and brownish colors to rocks. When they begin to decay, iron appears as a reddish stain upon the different constituents. It is iron that gives the reddish color to soil. The red color of bricks is due to the iron contained in them, and so with sandstones. The red paints used upon our houses also derive their color from iron.

Upon our earth iron rarely occurs in the metallic or native condition, but in combination with other substances. As it is valuable to us only in the metallic form, the ores of iron obtained from the earth all have to go through a process called reduction. These ores are oxides, a union of iron and oxygen, and we have to get the oxygen out of them.

Native iron, though not with certainty belonging to the earth, comes to us from the sky. It is the chief constituent of meteorites — those shooting stars which you have often seen flying across the sky at night. The most of these are burned up before reaching the earth, but some strike it.

Our earth is so heavy that many people have thought the interior must be made largely of iron. But as we have not been able to make holes much more than a mile deep, and the center of the earth is four thousand miles away, it is impossible for us to tell with certainty.

We will now study the important kinds of iron ore and learn, if we can, how they came in the rocks where we find them.

Perhaps the most of you have seen the reddish deposits in the bottom of stagnant water in swampy places. If a swamp should remain long enough, sufficient iron would collect there to form a bed of iron ore. Such a deposit is called bog iron ore. Much of the iron that we find in beds in the rocks was probably formed in bogs and swamps just as we see it forming to-day.

When a deposit of bog iron ore has been buried deeply with sands and clays, it is changed by heat and pressure into another ore of iron. When exposed upon the surface, by erosion, this is usually found to be hematite. This word means blood-like, and is given to the ore because it gives a red streak when scratched. Hematite is sometimes dull in color, and

MAGNETITE, LODESTONE.

at others has a bright, metallic luster. A variety of hematite, which occurs as an aggregate of scaly particles with a shining, metallic luster, is called specular iron ore.

To another ore of iron the name of magnetite is given; this because of its being attracted by the magnet. Magnetite is a widely distributed mineral, being found in small particles in most rocks. Crush a piece of rock to a fine powder, and place a magnet in the powder and move it about; you are almost sure to find that it has picked up some grains of this ore.

Magnetite is an iron-black mineral with a black streak. In addition to being distributed through the rocks it sometimes occurs in veins. Some of the beds of magnetite, which are being worked, are almost mountainous in size. We need have no fear of iron ore ever being used up.

A variety of magnetite is called lodestone. It is not only attracted by the magnet, but acts as a magnet itself. It will pick up little pieces of iron just as a magnet does.

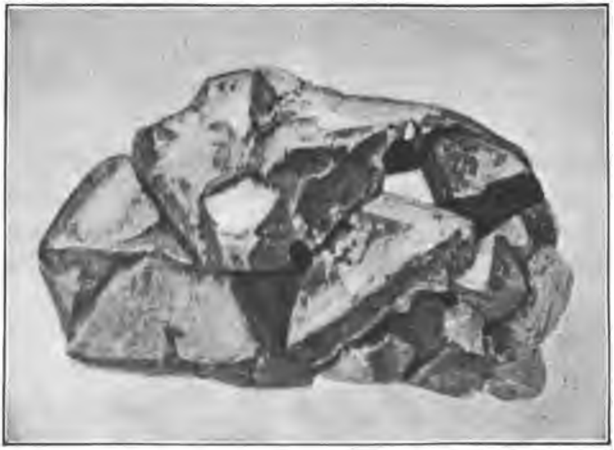
There is one mineral that you may get confused with magnetite. It contains chromium and oxygen, in addition to iron, and is known as chromite. It looks much like magnetite, but you can distinguish it from magnetite by the fact that it is not attracted by the magnet.

To obtain metallic iron from the ore, it is placed in great furnaces and mixed with limestone and charcoal,

or coke, the latter being a product of coal. A fire is lighted underneath, and as the ore melts, the liquid iron is drawn off at the bottom in long troughs made in sand. When cooled this product is known as pig iron.

From this iron, by processes of refining, wrought iron is made. Wrought iron is very pure, and is used for bridges, nails, etc. Steel is harder and more elastic; it is used for springs and rails. Our common dishes and stoves are made from cast iron.

In the presence of water iron is rapidly attacked by oxygen, which, if not hindered, would change it back into the oxide again. One method of protecting iron from decaying is by painting it; another is by galvanizing it, the iron being covered with a coating of zinc, which is not affected by the air.



MAGNETITE OCTAHEDRAL CRYSTALS.

IRON PYRITES.

The ores which we have been studying are oxides. Iron pyrites is a very common mineral, but it is not used as a source of our iron; it consists of iron and sulphur, and is therefore a sulphide of iron. It occurs in veins with quartz and other minerals, and is also scattered as grains, or little crystals, through many rocks.

The crystals of iron pyrites which you will see, are either cubes or modifications of cubes, but this mineral often occurs without crystal form. It has a pale brass-yellow color, and a metallic luster. It has a hardness equal to that of feldspar.

There are other varieties of iron pyrites with different appearance and crystal form. Marcasite, or white iron pyrites, has a pale grayish yellow color, and pyrrhotite a bronze yellow color.

Heat iron pyrites in a flame and you will get the suffocating odor of sulphur. Copper pyrites somewhat resembles iron pyrites, but it is more brassy. You will usually find a green stain of copper upon a specimen containing copper pyrites.

Siderite is an important ore of iron although not used as much as the oxides. It dissolves with effervescence in hydrochloric acid slightly warmed. Siderite is a carbonate of iron.

COPPER AND ITS ORES.

You are all familiar with copper, for it is used in many ways. It is perhaps next to iron the metal of most value to us. Let us see what we can learn about it.

Copper is one of the metallic elements. It is so soft as to be easily cut with a knife. Like gold, it can be drawn out into exceedingly fine wire or hammered into thin sheets. Its color is a peculiar red, known as copper red.

Since electricity has become so important, copper has become of great value as a conductor. You have all seen the lines of copper wire stretching across the country and carrying electrical force from one place to another.

Copper does not rust or corrode as easily as iron and is for this reason used as nails and as sheathing upon the bottoms of ships. Perhaps the most of us are more familiar with copper as it appears in our penny coins. Copper when mixed or alloyed with other metals forms substances of much value. With zinc it forms brass, and with tin a compound known as bronze, which is used in statuary.

If you have a specimen which you think contains copper it can be detected in the following way: Take a small piece and after crushing place it in a test

tube. Now pour into the tube a little nitric acid. If there is any copper the acid will dissolve it and give a green solution. Add enough ammonia water to the solution to neutralize the acid and it will turn a beautiful azure blue color.

Metallic or native copper is found in many places, particularly upon the shores of lake Superior in northern Michigan. Here are the most important mines of native copper in the world. The copper occurs in threads or grains scattered through an ancient volcanic rock. The Calumet and Hecla mine has been opened upon this copper deposit to a depth of four thousand feet. The copper is separated by water after crushing the rock. One mass of pure copper was found weighing over four hundred tons.

Copper also occurs widely distributed in combination with other substances, particularly sulphur. The most common of the minerals thus formed is chalcopyrite or copper pyrites, a sulphide of iron and copper. This mineral has a brassy yellow color, and is found associated with other minerals, particularly iron pyrites, in veins often many feet in thickness. When partly decomposed the ore is often iridescent. It is the most important ore of copper and frequently contains some gold.

You must not mistake chalcopyrite for gold. The latter metal is malleable and can be cut with a knife, while the copper ore is brittle. There are a number of other minerals in which copper is combined with sulphur, the most important of which is chalcocite,

This is a dark lead gray mineral with a bright metallic luster.

The copper sulphide ores when they decay change to carbonates. They do this by losing their sulphur and uniting with carbon and oxygen. There are two varieties of copper carbonate, one is green and is called malachite, the other is blue, and for this reason is termed azurite. They make very pretty specimens.

To obtain metallic copper from any of its ores requires a long process of roasting and smelting.

VIRGINIA CITY, NEVADA. SHOWING PILES OF WASTE ROCK TAKEN OUT OF MINES.

HOW SILVER OCCURS.

We all know something about the shining white metal which we call silver. We use it for money, we handle it at the table in the form of spoons, knives and forks. Beautiful and costly dishes are made of it.

Silver is sometimes found in the native state, but only in small quantities. It generally occurs combined with other substances forming minerals which have neither the appearance nor the properties of pure silver.

The metal has what we call a silver white color and metallic luster. It is very soft, but tenacious, and can be drawn out into fine wire. It is a more perfect conductor of electricity than copper. It is a little more than half as heavy as gold, and much more abundant.

Pure silver tarnishes easily in the air, particularly if the air contains any sulphur fumes. If a spoon which has been used in eating eggs be allowed to stand without washing a little time you will notice a dark stain. This is due to the sulphur of the eggs uniting with the silver and forming a sulphide of silver.

Silver is usually found in combination with one or more of the following minerals, sulphur, lead, copper,

arsenic, and antimony. Many mines in the western part of the United States and Mexico are known as silver-lead mines, being worked for the lead and silver contained in galena.

Argentite is a simple sulphide of silver containing eighty-seven per cent pure silver. It is quite soft and easily cut with a knife, which is remarkable, as most sulphides are brittle. Its luster is metallic and its color grayish black. A beautiful ore of silver, also a sulphide, is the red-silver or ruby-silver known as pyrargyrite.

Cerargyrite is a chloride of silver. It is also known as horn silver. It is a valuable ore, and like argentite is remarkably sectile. It is translucent and in color varies from light gray to green.

A delicate test for silver can be made in the following way: Take some of the material which you suppose contains silver. Dissolve it in a little nitric acid. Then to this solution add some hydrochloric acid. If there is silver present there will be formed a white curd-like precipitate of silver chloride.

Have you ever heard of the Comstock Lode? This is a great body of gold and silver bearing ore upon one of the desert mountain ranges in western Nevada. Many mines were opened here, and ores to the value of hundreds of millions of dollars were mined. A city known as Virginia City grew up about the mines and for many years it was a busy place. Now many of the mines are deserted and a large part of the population has moved away.

As silver formed the larger part of the product of these mines they may interest us. Let us take an imaginary trip to them when they were in their prime.

After climbing a long winding road we come in sight of great buildings with smoke stacks, surrounded with piles of dirt. They are situated upon the sides of the ridges and at the head of small cañons near the summit of the mountain.

After getting permission we go into one of the buildings and change our clothes. We put on light water-proof garments, for we shall find it wet as well as warm below. Now we step into a cage which is supported in a dark shaft by a steel rope. The engineer is given the signal and we begin to sink into the earth. It is as dark as night save for our flickering candles. The air which was at first cool becomes warmer. We are dropping down, down and when at last the cage stops we are half a mile below the surface. The water is dropping and gurgling around us and the air has become hot and almost stifling.

How glad we are now as we step out upon solid ground that our heavy clothes were left behind. We follow our guide for some time along the drifts and at last come to men at work. There they stand drilling the rock or shoveling ore into the cars, stripped to the waist, and with the sweat pouring from them almost in streams.

The thermometer is higher here than we have ever seen it upon the surface. It stands at 130 degrees. Water almost boiling is flowing past our feet. The

tools are so hot that the miners have to wrap them in cloth in order to hold them. How can they endure to work here? Great quantities of ice water are kept where the men can drink all they want, but even then they can remain at work no more than an hour at a time.

There was so much water in these mines that a tunnel several miles long was made lower down the mountain in order to drain them. After a number of years a depth was reached where, because of the increased water and heat, it was not possible to work longer, and the rich ores that extended still deeper into the earth had to be left.

There is a total length of tunnels in the mines of the Comstock Lode of about 150 miles, besides numerous great chambers large enough to take in an ordinary house. In these places large bodies of rich ore were found. Through the greater portion of the workings and especially in the great chambers the rocks had to be held up by huge timbers. The forests upon hundreds of square miles of the eastern slope of the Sierra Nevada Mountains were cut down to supply the necessary timber.

There were good opportunities in the mines of the Comstock Lode for observing how mineral deposits are formed. The deposition of minerals near the surface had ceased, but in the deeper regions, reached by the large mines, the hot waters are still at work slowly filling the fissured rocks with the rich ores.

GALENA, CUBIC CLEAVAGE.

LEAD AND ZINC.

We have just studied several metals which occur both in the native state and in combination with other substances. Now we want to take up several that are probably not found native. These are lead, zinc, and tin. Lead and zinc occur in combination with sulphur. Tin is found in the form of an oxide. In order to get these substances into the metallic state they have to go through chemical treatment in what are termed smelters.

The common ore of lead is galena. You have seen it in the form of dark gray cubical crystals with a bright, metallic luster. Galena is quite soft and brittle. The mineral occurs commonly in cubical crystals. It is interesting because of the very perfect cleavage parallel to the sides of the cube. This is

called cubical cleavage. Break a mass or crystal of galena and it will form a large number of little rectangular blocks.

Galena occurs in veins in many different kinds of rocks, but more commonly in or on the edge of a body of limestone. We almost always find minerals occurring in groups. Certain minerals seem to like each other's company. Gold occurs commonly in veins of quartz. Galena occurs rather in veins of calcite and in the company of zinc ores. Lead and zinc in most mining regions carry a varying amount of silver.

You can readily tell that galena contains sulphur by heating a bit of it in a hot flame. You will get the strong odor of sulphur. If you place some galena in a test tube with a little nitric acid the lead will be dissolved and the sulphur set free will gather on the top of the liquid in a little spongy mass.

Lead is one of the heaviest of the metals. It is soft and easily worked and is for this reason used for many purposes. It is made into pipe for carrying water. Mixed with tin it forms an alloy known as pewter. We form an alloy by melting the metals together. In making shot and bullets a little arsenic is mixed with the lead to make it harder.

The white lead which painters use is made from another ore of lead called cerussite. This is the carbonate of lead. Sometimes you will find it upon the outside of a piece of galena. The oxygen of the air

has in such cases attacked the sulphide and changed it to the carbonate.

The common ore of zinc is sphalerite or zinc blende. Miners sometimes call it black jack. They do not like to see it in a vein with ores of other minerals because it makes them more difficult of treatment.

SPHALERITE CRYSTALS ON DOLOMITE.

Sphalerite occurs in masses of crystals of a pale yellowish brown color. Sometimes they are nearly black. The mineral has a resinous luster and is more or less translucent. By this we mean that it will let light pass through, but we can see no definite image as when looking through a glassy mineral.

Zinc is alloyed with copper to form brass. This artificial product is used a good deal because of its attractive color and comparative cheapness. It is malleable and ductile, like copper.

Zinc is not readily attacked by the air and so it is used in many places where iron would rust. We are familiar with it as a coating for iron, the product being called galvanized iron.

We can distinguish sphalerite very easily from galena although they often occur in the same specimen. Galena is much softer and almost twice as heavy as sphalerite. Galena has a dark gray color and is opaque, while sphalerite is brownish yellow and translucent. Galena has cubical cleavage while sphalerite has not.

There are a number of ores of zinc, but the most of them are not common. Smithsonite is, perhaps, next to sphalerite, the most common. It is the carbonate of zinc.

TIN.

Tin is one of the important metals. It rarely if ever occurs in Nature in the metallic state, but commonly as the oxide. This we call cassiterite. The name is a very old one. It is supposed that it was the ancient name of the British Islands. The earliest that we know of tin it was mined in Cornwall on the southwestern coast of England. The ancient Phœnicians were great sailors and took, what were then, long and dangerous voyages to obtain this metal. They gave the name by which the islands were known to the mineral which was of so much value to them.

Tin is not so abundant as are lead, copper, and zinc. It is found in quantities sufficient to make the mining of it profitable in only a few places in the world. The most of our tin comes from England, Australia, and the Malay Peninsula. The tin mines of Cornwall are the most noted. They have been worked as we have seen for a long time. Some of them are deep and extend out under the ocean making mining quite dangerous.

Cassiterite has a brown color and a bright adamantine luster. By adamantine we mean the luster of the diamond. Sometimes cassiterite is found in little sparkling crystals, at other times in massive form.

It is also characterized by a high specific gravity ; that is, it is very heavy.

Cassiterite does not occur in veins similar to those of the minerals we have just been studying. Deposits of lead and zinc ores are more commonly associated with limestone rocks, and the veins carry little quartz. Cassiterite, on the contrary, is found in quartz veins in granite or related rocks. It often has associated with it a large amount of tourmaline and frequently iron, and arsenical pyrites.

Much of the tin mined is called stream tin, because found in the gravels of streams. Cassiterite, like gold, is heavy and not easily decomposed, so that when the rocks containing it crumble, the mineral, in the form of grains of varying size, is washed into the creeks and mixed with the gravel.

Metallic tin is harder than lead but softer than gold. It is not often made into dishes of solid tin, but is employed chiefly as a coating for sheet iron. Iron is stronger than tin, and besides, tin is so valuable that dishes of the solid metal would be much more expensive.

Our common tin dishes, as you all know, are not solid tin. The coating of tin wears off exposing the sheet iron beneath. After a little time the iron rusts and a hole appears in the dish.

Copper and brass are easily tinned by dipping them into the molten tin. In the case of sheet iron the process is more difficult. In making the tin plate the sheet of iron is first dipped in hydrochloric

acid and then cleansed. It is next dipped in melted fat to dry and warm it, and then into the molten tin.

When tin is alloyed with lead the poorer classes of tin plate are made. We should be careful about the kind of tin cans which we use for preserving fruit, as the lead in tin is much more easily dissolved by the acids in the fruit, and the salts formed with the fruit acids are poisonous.

Tin forms many alloys. With copper it makes bronze, valuable for bells, guns, and statuary. Alloyed with lead it forms pewter and solder.

THE STORY OF QUICKSILVER.

Mercury, or quicksilver, as we often call it, is a very interesting metal. We have all seen it in the bulb of the thermometer and wondered at its rising and falling in the glass tube with every change in the temperature.

Native mercury rarely occurs in Nature. The mercury which we use has been obtained from the chief ore of mercury called cinnabar. Mercury is the only metal which is liquid at the ordinary temperature. It has a brilliant metallic luster and is very heavy. It is thirteen and a half times heavier than water and is exceeded in weight only by gold and platinum.

We can readily understand why the name quicksilver was given to this metal. In its bright luster it resembles silver, while its liquid condition, and its breaking into globules when poured, led to its being termed living silver or quicksilver.

For a long time quicksilver was not thought to be a metal, but when it had been exposed to a very low temperature and frozen, it was found to be malleable. Then it was classed among the metals.

Cinnabar is a sulphide of mercury. It is found as little crystals lining cavities or as streaks and grains in veins of silicious material. It has a peculiar

cochineal-red color and a scarlet streak. Its color is much brighter than that of the red oxide of iron, and you will not easily confuse it with any other mineral.

Cinnabar is a rather rare mineral. It is mined chiefly in Spain, Austria, and California. Pure mercury is sometimes found scattered through this ore in the form of little globules.

We will visit one of the mines in California and see what we can learn. The New Almaden mine is nearly two thousand feet deep and has produced a great deal of mercury.

As we go down the shaft the air becomes warm and close. Quicksilver mines, as well as those where lead is mined, are very unhealthy places because of the vapors and poisonous dust which are taken into the lungs. In this way the body is slowly poisoned and serious diseases result.

In the lower drifts of the mine men are at work upon a body of honeycombed quartz containing streaks and specks of the bright red cinnabar. The men are working with cloths over their mouths to keep out as much as possible of the dust. In some mines the dust is so bad that only Chinamen will work in them.

After the ore reaches the surface it is sent to the roasting furnace. Here it is broken up into small pieces and treated to a great heat. Quicksilver is very volatile. The heat drives the metal out of the ore in the form of a gas. It is conducted through an inclosed channel to a reservoir which is kept cool.

Here the vapor is condensed and the metal recovered in the condition in which you see it in the thermometer. The mercury is then placed in iron flasks to be sent to market. These flasks are about one foot high and in shape that of a slender barrel with an opening in one end which is closed by an iron plug. You would be surprised at the weight of one of these flasks if you tried to lift it.

Quicksilver has many uses. With tin it forms an amalgam for the backing of mirrors. We have already learned about its use in mining; how it has an attraction for the particles of gold and with them forms an amalgam. The metal does not become solid until at a temperature of about 40 degrees below zero, Fahrenheit. Mineral substances expand with heat and contract when cold. This property makes liquid mercury of great value in thermometers.

One form of mercury is used in medicine. It is termed calomel and is very poisonous. The brilliant paint which we call vermilion is made from the red cinnabar.

Mercury is also used in barometers. By showing the pressure of the air a barometer enables us to tell how high a place is above the level of the ocean. We do not feel the pressure of the air because it is equal in all directions. At the ocean level it exerts a pressure of fifteen pounds to the square inch. As we rise from this level we leave a part of the air below us and the pressure becomes less.

To make a mercurial barometer we take a tube

of glass about thirty inches in length and fill it with mercury. Then the tube is inverted in a dish of mercury. That in the tube will fall until the pressure of the air upon the mercury in the dish exactly balances it. At the sea level the mercury will rise in the tube of a barometer to a height of about thirty inches. In climbing a mountain the mercury will continue to fall as the pressure of the air becomes less.

PLATINUM—THE HEAVIEST MINERAL.

The heaviest substance known is the metal platinum. Like gold, it shows little affinity for other substances and occurs almost exclusively in the metallic state.

Platinum has a dull gray color with a luster not as bright as tin. When found in Nature it usually contains some impurities such as iron and some of the rare metals. These reduce its specific gravity more or less, but when purified and prepared for laboratory use it has a specific gravity of between 21 and 22.

Although not a beautiful metal, platinum has certain properties which, with its rarity, make it fully as valuable as gold.

The most of our platinum is obtained from river gravels where it occurs with gold. The Ural Mountains are the chief source, but small quantities are found in California and other parts of the world. It appears that in California the miners have been throwing away platinum, not knowing the value of the grains and nuggets of this heavy gray metal which collected in their sluices with the gold.

Platinum will not melt except at the most extremely high temperature and is not attacked by any of the acids. It differs in these respects from

gold, which is easily melted and is dissolved by aqua regia, a mixture of nitric and hydrochloric acids.

On account of the properties mentioned, platinum becomes very valuable in the laboratory. It is also malleable and ductile so that fine wire can be made of it and dishes that are thin and light. It is made into little crucibles shaped much like a thimble, only larger. In these are placed substances which the chemist wishes to melt and analyze.

Platinum is also used by dentists, as well as in incandescent electric lamps and photography.

In the earlier part of the last century platinum was coined into money in Russia. It was not used long, however, because it had no fixed value in the markets of the world. Anything used for money must have a fixed value.

ALUMINUM — THE LIGHTEST METAL.

I am sure you have all seen metallic aluminum. It has been made into dishes, combs, and many other things. The peculiar and interesting thing about this metal is its wonderful lightness.

Silver is ten times, and tin about seven times, heavier than water. Aluminum, although having much the appearance of these two metals, is only two and a half times heavier than water. This property of lightness should make it of special value in the construction of boats.

Metallic aluminum does not occur in Nature. There appears to be a great attraction existing between the element aluminum and many of the other elements. Next to oxygen and silicon, aluminum is the most abundant of all the elements entering into the crust of our earth. It is found everywhere. It forms a part of the clay over which we walk, of shales, and slate, and of many of the minerals which make up the crystalline rocks about us.

Although so abundant it is only recently that aluminum has come into common use. This is because of the difficulty which was found in separating it from the other elements with which it is combined. Only a few years ago aluminum was very expensive.

Metallic aluminum is a tin-white substance which can be drawn into fine wire and hammered into thin sheets. It is not attacked by the air, so that implements made of it retain a clean, bright appearance.

Clay, as you know, comes mostly from the decomposition of the feldspars in granite and other rocks. Clays are valuable, as they form the chief ingredient of various kinds of pottery, as well as of the dishes which we use. Sewer pipe and brick are also largely clay.

Clay is a silicate of aluminum containing water; that is, it is composed of aluminum, silicon, oxygen, and water. Abundant as clay is, metallic aluminum is not obtained from it, but from a much rarer mineral called beauxite. This is an oxide of aluminum containing water. It occurs in earthy masses resembling clay.

Besides clay, or kaolin, as pure clay is termed, and beauxite, there are other minerals containing alumina. We will take up first corundum, the oxide of alumina. This mineral is next to diamond the hardest of all known substances. The impure variety of corundum is known as emery. It is a dark mineral looking much like fine-grained iron ore. Emery is crushed to a powder and used for grinding and polishing hard substances.

The pure variety of corundum forms a beautiful gem known as sapphire. The different varieties of sapphire are named according to their colors. There

is the ruby, which is red, the oriental topaz, which is yellow, the oriental emerald, green, and the oriental amethyst, purple. These are much used as jewelry.

Another mineral formed of alumina, silicon, and oxygen is called topaz. This is also a precious stone exhibiting many different colors. It is harder than quartz and softer than corundum.

Does it not seem strange and interesting that the same metal when pure presents such a different appearance, than when combined with other substances? Metallic aluminum, soft clay, and the hard and beautifully colored sapphire seem to have nothing in common.

SOME LESS COMMON MINERALS — ARSENIC, ANTIMONY, NICKEL, MANGANESE.

Arsenic is rarely found native. It is a widely distributed mineral, but generally occurs in small quantities in any one place.

Arsenic is combined with sulphur, forming sulphides, and with sulphur, iron, nickel, silver, copper, and lead in various minerals.

The mineral from which the most arsenic is obtained is one of the pyrite group called arsenopyrite. This mineral is composed of iron, arsenic, and sulphur. Arsenopyrite is closely related to iron pyrite and marcasite, which you remember are sulphides of iron.

Arsenopyrite has a hardness of feldspar and consequently will scratch glass. The name pyrite was given to several minerals of this group because of their giving out sparks of fire when struck with steel. The word pyrite is derived from one meaning fire.

Arsenopyrite has a silvery white color, and this will help you to distinguish it from the different varieties of iron pyrites as well as the fact that the arsenic which it contains gives out a smell of garlic when the mineral is heated.

Arsenic has many uses, but we have to be careful of it for it is very poisonous. As pigment, it is used to

give color to various manufactured articles, such as paper. It is of value as a preservative. The skins of animals when mounted are covered with it to keep the insects from injuring them. In the form of Paris green arsenic is used to kill insects which injure plants. It is often taken in very small quantities as a medicine.

Native antimony is not a common metal. It is usually found combined with sulphur, forming the mineral stibnite. It has a bluish gray color and bright luster, especially upon a fresh cleavage surface. It is so soft as to be scratched with the nail and easily fused. Metallic antimony is obtained by heating the ore in the proper kind of furnace and collecting the melted metal.

Stibnite sometimes occurs in groups of long, shining crystals. These are obtained in California and Japan. Antimony is alloyed with lead and tin and used for many purposes. One of the most important of its uses is in the manufacture of type metal.

What do we know about nickel? The boot-black says "Shine your boots for a nickel." We are perhaps most familiar with this metal in our five-cent coins. These coins are not pure nickel, however, but contain some copper.

Nickel is frequently used as a plating upon steel instruments, as it does not rust readily. Nickel occurs combined with sulphur and arsenic in some of the rarer minerals, and also in pyrites, especially those of iron and copper.

If you have never seen a piece of manganese ore you have at least observed the strangely branched markings found upon some stones. Break open a piece of rock along a faint crack and you are quite sure to see fern or tree-like markings with the most delicate outlines. The dark substance forming these markings is not a plant, but the mineral known as pyrolusite, an oxide of manganese. The markings are known as dendrites.

Pyrolusite is a black mineral with a black streak. It is found in small quantities in many rocks and is often difficult to distinguish from iron without making a chemical test. When pyrolusite occurs in veins of sufficient size it is mined. It is used in making steel and as a coloring matter in pottery.

The delicate dendritic markings in the rocks are due to the fact that water takes this black oxide of manganese into solution. As it slowly penetrates and seeps through the fine seams in the rocks the manganese is deposited, forming the delicate markings.

SULPHUR.

Sulphur is an interesting mineral. It was believed long ago that sulphur was the principle of fire. It was called brimstone or burning stone.

Sulphur is one of the non-metallic elements. It occurs both native and in combination with other elements. It has a bright yellow color, resinous luster, and is very soft and light. Although you can cut it with a knife, yet if struck a sudden blow it will break into fragments. The specific gravity of sulphur is about 2, which makes it only twice as heavy as water.

If we take a bit of sulphur and hold it in the flame it quickly melts and begins to burn, giving out a strong, suffocating odor.

Sometimes we find sulphur in beautiful crystals with sparkling faces. When not crystallized it occurs in masses which break with a conchoidal fracture, a fracture similar to that of flint or obsidian.

Native sulphur is found either where there have been hot springs with sulphurous vapors, or in the neighborhood of volcanoes. Sulphur vaporizes very easily and in this form comes up with other gases from far down in the earth.

Sulphur is abundant in some of the quicksilver

mines of California. These mines are in a volcanic region where there are many hot mineral springs. Water, almost boiling, flows from several of the mines and if we could make a trip into one of them we should see chambers in the rock lined with sparkling crystals of sulphur. These are formed by condensation of the sulphur in a gaseous form.

The larger part of the sulphur used comes from the volcanic island of Sicily in the Mediterranean sea. Here the people employ a very wasteful method of getting it. The sulphur is found more or less mixed with dirt and rock upon the slopes of a volcano. The sulphur is dug out and together with the impurities is piled in shallow holes in the ground. The whole is then set on fire and as fast as the sulphur melts it is dipped up from the bottom of the hole. We can hardly imagine how sulphurous the the air must be, for we are almost choked sometimes when we have breathed the fumes from the small amount of sulphur on the end of a match.

In Mexico sulphur is found in the crater of one of the highest volcanoes. Men have to climb the mountain and then go down into the crater to get it. The work is hard and dangerous.

Another source of sulphur is iron pyrites. You know that sulphur is found combined with many other elements forming sulphides. Iron pyrites is perhaps the most abundant of these sulphides. To obtain the sulphur from iron pyrites the mineral is placed in a furnace shaped somewhat like a limekiln.

A fire is started underneath and the pyrites is roasted. The sulphur is driven off in the form of vapor and in cool chambers is condensed again to solid sulphur.

Sulphur is found combined with a number of substances forming sulphates. In epsom salts, for example, we have a union of sulphur, oxygen and magnesia.

Sulphur occurs widely distributed in small quantities in animal and vegetable tissues. Eggs contain it, as is shown by their tarnishing silver. Can you mention a number of uses of sulphur?

GYPSUM CRYSTAL—SELENITE CRYSTAL.

GYPSUM.

Gypsum is an interesting mineral which appears in several attractive forms. It is a sulphate of calcium, containing calcium, sulphur, oxygen, and water.

Gypsum is one of the softest of minerals, for you can scratch it easily with the finger nail. It is number two in the scale of hardness. It occurs in different colors, such as white, gray, brown, and pink, and is found in translucent granular masses or in transparent crystals.

The most of our gypsum is obtained from layers or beds lying between strata of sedimentary rock such as clay, shale, or sandstone. Deposits of gypsum and salt are very often found together. These minerals both occur dissolved in sea water.

It is thought that long ago beds of salt and gypsum were deposited in arms of the ocean which were cut off from the main body of water. The water in these finally dried up and the substances that were contained in the water were left upon the bottom.

Some of these deposits were covered with sands and clays and deeply buried in a manner similar to coal. They were hidden for ages in the earth, and at last when disturbances of the rocks occurred they were lifted above the water, and erosion carried on by the streams exposed them to our view.

We sometimes find gypsum in veins where the material was gathered by percolating water. Beds of clay and shale often contain much gypsum distributed through them. Water soaks into these beds and dissolves out the gypsum, carrying it to some other place where there are fissures in the rocks, and there deposits it.

The common granular variety of gypsum is used for a number of purposes. To make plaster the mineral is burned in kilns or furnaces until the water it contains is driven off, when it turns white and crumbles to a powder. It is now called plaster of Paris. This name was given because the mineral was first quarried and treated in this way near the city of Paris.

You can easily make some plaster of Paris by heating a little gypsum in a tube closed at one end. The water will be driven off and you can see it condense upon the sides of the tube.

When plaster of Paris is mixed with enough water to thoroughly moisten it the material "sets," shortly becoming hard like a rock. For this reason plaster of Paris is very valuable for making casts and taking impressions of objects. It is also used as a finish for plastered walls, in vases, images, etc.

Soils which do not contain the necessary food for plants have to be enriched and gypsum is often used for this purpose.

The clear variety of massive gypsum is called alabaster. It is used for making vases, statuary and other ornaments. It is very fine grained and exhibits different colors.

The crystalized variety is called selenite. It has a pearly luster and is often as clear as glass. The tabular crystals of selenite exhibit a very perfect cleavage and can be split up into thin plates. Sometimes crystals are found which will afford cleavage plates nearly a yard across. The plates are flexible but not elastic; this is one distinction between them and the cleavage plates of mica, which are perfectly elastic.

Satin spar is a fibrous variety of gypsum having a delicate opalescent or silky luster.

BARITE CRYSTALS.

BARITE.

Barite is another sulphate much used in the arts. The base of this mineral is Barium.

If you pick up a piece of barite you will be surprised at its weight. Calcite, which it often closely resembles, has a specific gravity of 2.6, while barite is nearly twice as heavy, showing a specific gravity of 4.5. Because of its weight it is often called heavy spar. It is usually white, although some varieties, containing impurities, are nearly black.

Barite is a common mineral in some mining regions, being most often associated with lead ores.

When pulverized, barite is used to adulterate white lead, and even sugar. It is employed in the process of beet sugar manufacture and as a glaze for paper.

The uncommon weight of barite will enable you to tell it, for no other mineral resembling calcite has so high a specific gravity.

WHAT WE MEAN BY SPECIFIC GRAVITY.

If you examine a book upon mineralogy you will see that it is stated of each mineral described there that it has a certain specific gravity. Now we want to find out what is meant by this expression, "specific gravity," and how it is determined.

The specific gravity of a substance is its weight when compared with an equal volume of another substance which we use as a measure. When we go to the store to buy sugar and flour we do not buy them by the quart but by the pound. We get a certain weight of sugar or flour and do not pay any attention to the size of the packages. One substance may be so light that a pound package will be quite bulky, compared with that of a heavier substance. Specific gravity does not have to do with equal weights of substances, but with equal volumes. If we bought flour and sugar by the quart we should find that a quart of one would weigh more than a quart of the other.

To express the specific gravity of liquids and solids we must have a measure. This measure is water, pure distilled water, at a certain temperature. Then we can determine the weight of different substances as compared with this standard measure.

We must remember in determining the specific gravity of different substances that they do not weigh

in proportion to their size. A little bit of lead weighs as much as a great quantity of aluminum.

Distilled water is used as the measure, because it is perfectly pure. All spring water contains more or less mineral matter in solution. In getting the specific gravity of lead we might use the following method. We could weigh carefully a cubic foot of water and then a cubic foot of lead. This done we would divide the weight of the lead by the weight of the water. This would tell us how many times heavier the lead is than water. In the same way we might determine the specific gravity of silver. We should find it to be about 10.5 times heavier than the water; platinum we would find to be about 21 times, and aluminum only 2.5 times heavier than water.

This method is inconvenient, however, because of the difficulty of getting exact volumes of the substances to be weighed. The manner in which specific gravity is actually measured is as follows. Weigh a little piece of the mineral upon a pair of scales in the air. Then place the mineral suspended from one arm of the scales in a dish of water and get its weight when in the water.

If you have ever picked up a piece of rock under water you have noticed how much lighter it feels in the water than in the air. This is because the water is denser than the air and bears it up more.

We find how much less the mineral weighs in the water than in the air, and then divide the weight in the air by that amount. This will give the number

of times heavier the mineral is than the same bulk of water. It weighs as much less as the weight of the water displaced.

The weight of each mineral when pure is always the same. This fact aids us in distinguishing the different minerals.

All minerals, except petroleum, are heavier than water. Can you explain now how it is that a ship made of iron, a metal many times heavier than water, can carry so heavy a load?

We can determine the specific gravity of gases as well as that of liquids and solids. Although gases are invisible we weigh and measure them. Hydrogen is the lightest of all the gases and is taken as a measure for the others. We have to use equal volumes of gases under the same pressure to get at their specific gravity.

A TOURMALINE MINE.

Tourmaline is found either scattered through rocks of the granitic type or in veins penetrating these rocks. The more common variety of tourmaline is black and opaque, but it is sometimes found translucent and brightly tinted green, red, and brown, forming one of the most beautiful and valuable minerals.

Tourmaline occurs usually in slender crystals with three, six, or nine sides. The crystals may be single or grouped in a radial manner forming little bunches. Sometimes the crystals reach a length of nearly a foot, but usually are much smaller. We frequently find them in the form of minute needles.

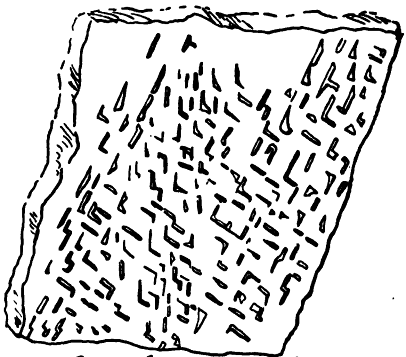
Tourmaline is brittle and has a hardness as great as quartz. The common variety is jet black with a bright luster. The only minerals that you are apt to confuse with it are hornblende or augite, but both of these minerals are softer and show smooth cleavage planes. Tourmaline breaks with a rough fracture, the pieces looking much like coal.

The clearer and more brightly colored tourmaline crystals are often of great value as gems. Delicate shades of green and red and brown are sometimes mingled in the same crystal. One end of a crystal may be green and the other a ruby red, with all inter-

mediate shades between, or the inside may be a rich ruby red with a rim or layer of delicate green on the outside. Single crystals showing such colors and free from cracks are worth several thousand dollars.

The variety exhibiting a ruby red color is called rubellite. This mineral contains the rare element, lithia.

In the mountains of southern California there are some wonderful tourmaline mines which are well worthy of a visit. One of them is situated upon a great vein outcropping along a mountain slope. This vein contains several varieties of tourmaline as well as other minerals.



Graphic granite

The vein is different from ordinary veins. It consists largely of pegmatite or graphic granite. The quartz and feldspar are curiously mixed, the quartz being in long blades or needles which penetrate the feldspar crystals. If you break a piece of the

feldspar along a cleavage plane you will obtain a smooth, bright surface with curious little figures of quartz scattered over it. These look like the writing characters of a people that lived long ago, and for this reason the rock is called graphic granite. The word graphic is from an ancient word meaning to write.

The graphic granite contains muscovite mica in addition to quartz and feldspar. It occurs in much larger masses than in ordinary granite You may be able to get out some of the cleavage scales half an inch across. What a delicate pearly luster they have. In some parts of the vein mingled with the quartz, feldspar, and mica, there are slender crystals of black tourmaline.

At a point in the vein where the tourmaline mine has been opened we find a deposit of a very different character. Here is a great mass of rock of a delicate purple or lilac color made up of what appears upon close examination to be tiny scales of mica. This is called lithia mica or lepidolite. It is a rare mineral usually found in the company of the pink tourmaline, which, as we have learned, also contains lithia. You have perhaps heard of lithia water, which is obtained from some springs and is valuable as a medicine.

More attractive even than this delicate lithia mica are the bunches of crystals of the pink tourmaline known as rubellite. The slender crystals of rubellite are grouped in a radial manner and are scattered

through the mica in such a way as to present the most beautiful appearance.

In some parts of the vein there is found a little green tourmaline, so that we have here together red, green, and black tourmalines.

In another tourmaline mine a few miles away there are crystals of tourmaline an inch and a half in diameter and eight inches long. Some of these crystals present the most beautiful shading of red and green.

When cut into settings for rings the red tourmaline looks much like a ruby, but the real ruby is quite a different thing.

GARNET.

Garnet is a common mineral. You may find it in the crystalline rocks, such as gneiss and mica schist, as well as in the gravels of many streams. The composition of garnet varies greatly and with this the color. Garnet is usually opaque or translucent, with red, brown, yellow, or blackish colors. It is brittle and hard, the hardness being about the same as that of quartz.

The common color of garnet is red. If you find a piece of rock with little roundish red grains or crystals scattered through it you may be quite sure that they are garnets. The most of the garnets that you will find vary in size from that of a pin head up to one quarter of an inch in diameter. Rarely they occur much larger, even weighing several pounds.

The little crystals of garnet are at first sight apparently round, but if you will dig several perfect ones out of the rock and examine them carefully you will discover that each has twelve smooth faces. More rarely you will find them having twenty-four faces. When rocks decay the garnets that are contained in them fall out and are washed into the streams. As they have a rather high specific gravity they reach the bottom of the gravels and mingle with any other heavy minerals which happen to be there.

If you will wash out some of the gravel in most any stream you are quite likely to find a few garnets. If your home is near the ocean look for some of the darker sand which the waves leave here and there. Place a little of it upon a sheet of white paper and look at it with a pocket microscope. You will find many tiny red grains. The most of these are garnets. Their smooth faces have been destroyed by being washed around for so many years. Garnet is as hard as quartz and stands being thrown about by the waves as well as that mineral.

The garnets obtained from gravels are often called rubies, but rubies are much more rare and it is not likely that you will find any. The clear red garnets are of value as gems, but it is seldom that such garnets are found.

ASBESTOS — THE FIBROUS MINERAL.

Asbestos is the only common mineral that always occurs in fibrous masses. Although it differs much in appearance from hornblende, yet asbestos belongs in the same family, that is, the amphibole family. The mineral which asbestos most nearly resembles is chrysotile, which we shall study in connection with serpentine.

The word asbestos means inextinguishable, unquenchable. The name was applied to the mineral in question by the ancient Greeks because it was not changed by heat. Wicks made of the fibres were used in the sacred fires of their temples.

Cloths of various sorts have long been made from the fibres of this mineral. Napkins made from them could be thrown into the fire and burned clean. At one time the mineral was supposed to be a variety of flax which was incombustible.

The fibres of asbestos have a silky luster, and in the finer varieties they are thoroughly flexible. In color asbestos is white, gray, green, or even quite dark.

The peculiar properties of asbestos well adapt this mineral to uses where it has to come in contact with great heat.

At the present time asbestos is valued for quite

a number of purposes. It is used for lamp wicks, it is made into firemen's clothing, and mats for use in the laboratory. It has been found valuable as a packing to be put about boilers of steam engines. It is also ground and mixed in paint in order to make a fire-proof covering for buildings. Asbestos is found in irregular veins where there are bodies of serpentine and related rocks.

ASBESTOS.

ACTINOLITE.

Actinolite is another member of the amphibole family. It is a pretty mineral occurring in bright green crystals. The crystals have a bladed shape and are massed together in radiated aggregates. There is no other mineral that closely resembles actinolite, so that you will have no trouble in telling it when once you have seen it.

TALC — THE SOFTEST MINERAL.

Talc is interesting because it is the softest mineral with which we are acquainted. It is scratched very easily with the finger nail and is used as number 1 in the scale of hardness. Talc is also distinguished by its peculiar greasy or soapy feel when the fingers are passed over it. Talc occurs foliated, that is, in leaves or scales, and also in a fine grained, compact form. The latter variety is termed soapstone.

Foliated talc varies in color from nearly white to different shades of green, and presents a delicate, pearly lustre. It often forms very attractive specimens.

The folia or scales of talc are frequently almost transparent. They can be split thin like mica, but differ from mica in not being elastic. If you bend a thin scale of talc it will not spring back, but remains bent.

Soapstone, the compact variety of talc, also varies from white to greenish in color. It is quarried and used for a number of purposes. Bricks or slabs cut from soapstone retain their heat for a long time, making them of value in fire-places and as foot warmers.

Ground talc is used to give a gloss to wall paper. It is also used in glass making, and as a face powder.

Talc results from the alteration of other minerals. It is found particularly in regions where the crystalline rocks have been squeezed and altered because of movements of the earth's crust.

SERPENTINE.

Serpentine is another interesting mineral substance. We call it a mineral because it has a fairly constant chemical composition, and we call it a rock because it forms such great masses in the crust of the earth. In California serpentine outcrops over thousands of square miles.

Serpentine, like talc, has been formed by the partial decomposition, or perhaps we might say alteration, of other minerals. The chief source of serpentine is an igneous rock, consisting, in great part, of augite and olivine.

Serpentine is a little harder than talc. It varies in color from green to almost black, and has a somewhat resinous luster.

It occurs either in shaly masses or as solid rock. Some varieties show richly variegated colors and are cut and polished for ornaments.

A fibrous variety of serpentine is called chrysotile. It looks much like asbestos only that it has a more silky luster and a greenish to yellowish brown color. This mineral occurs as veins in serpentine.

EPIDOTE.

Epidote is quite a common mineral in many rocks. It is what we call a secondary mineral. By that we mean that it was formed in the rocks, not at the time they were made, but later, as the result of the decomposition of minerals already present.

Epidote has a yellowish green color, and a hardness fully as great as feldspar. You are most likely to find epidote scattered through the rocks in little green patches or streaks. Epidote sometimes forms pretty crystals about the sides of cavities in the rocks, but they are rare and you may not find them.

You will not easily mistake any other mineral for epidote. Actinolite has a bright green color, malachite has a darker and bluer green color, while epidote is yellowish green. Many people think that all green stains in rocks indicate copper, but you must not make that mistake.

Epidote is not used for any purpose, but as it is quite an important rock-forming mineral we want to be able to distinguish it when we meet it.

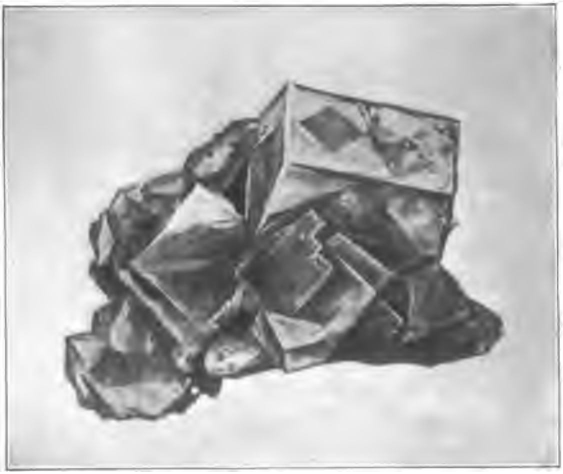
FLUORITE.

Fluorite is a rare mineral, but is quite important. It is formed of calcium and fluorine. It is found in veins in the rocks either in masses or in cubical crystals of many different colors such as blue, purple, green, yellow and red. The same mass of crystals often shows a variety of colors, and altogether the specimens of this mineral are very attractive. Crystals of fluorite when colorless look almost exactly like rock salt. You can easily distinguish salt, however, because it will dissolve in your mouth, giving the well known taste. When heated gently in a closed tube, fluorite becomes phosphorescent, that is, it glows or gives a faint light.

The chief use of fluorine is in the manufacture of hydrofluoric acid. This acid is a powerful solvent and attacks almost everything. The easiest way to keep it is to place it in bottles made of wax.

Hydrofluoric acid is used in etching glass, and also as a solvent in the chemical laboratory. You have propably all seen glass on which there has been etched various designs and figures.

FLUORITE, OCTAHEDRAL CLEAVAGE.



FLUORITE, CUBIC CRYSTALS.

APATITE CRYSTAL IN CALCITE.

APATITE.

The mineral apatite is formed of calcium, fluorine and phosphoric acid. It is used as number 5 in the scale of hardness. Apatite is a mineral with a whitish or bluish color and glassy luster. It is found in some of the crystalline rocks.

You might mistake apatite for quartz, but its hardness is so much less that you can always tell it by using a knife. It is only a little harder than fluorite, but the shape of the crystals is different.

Apatite is mined for the phosphate which it contains. The phosphates are valuable as fertilizers of land. Plants need phosphorous and many soils do not contain enough.

HALITE CRYSTAL.

THE STORY OF COMMON SALT.

The mineralogical name for common salt is halite. We all know how salt looks and tastes. If you place some salt in a dish of water it will dissolve, and when the water has evaporated it will appear again showing little cubical crystals.

Salt is a chloride of sodium; that is, it is formed of chlorine; a suffocating, poisonous gas, and the element, sodium, a combustible solid. There are many chemical compounds known as salts, but in common language the term is understood to apply to the substance about which we are talking.

We all know how salt the ocean water is. Men have perished upon the ocean with water all around them, being unable to drink it because of the salt. There are many lakes also that are salty, some of

them richer in salt than the ocean. Salt is present also in the water of some springs. Such springs are frequented by wild animals, for they like salt almost as well as we do.

Salt is also dug out of the earth. It is then called rock salt. There are extensive mines in different parts of the earth devoted to obtaining the salt buried in the earth.

CRYSTALS OF ROCK SALT.

Would you not like to know why so much of the water upon the earth is salty and how the great beds of rock salt were formed?

Great Salt Lake of Utah is a most remarkable lake. The water contains so much salt that you cannot sink

in it. If we can find out how this lake became salty we shall understand why the ocean is salty. The lake is like a small ocean.

If we study all the lakes that we know about we shall find that those that have water running out of them are formed of fresh water. When we drink the water it tastes as pure as spring water. If we go to a lake that has no outlet, no water running out of it, we shall find the water filled with different salts, among which common salt is often the most noticeable.

Why is one class of lakes fresh and the other salt? The rocks which make up our earth have scattered through them very small quantities of the elements which form many of the salts. The rocks, as we have already learned, crumble slowly as the years pass. The rains wash the decomposed rock, in the form of sand and clay, down to the streams and they carry this waste to the ocean or some of the lakes which dot the surface of the land.

If the lake into which the water flows has an outlet, the material dissolved in the water is carried through it and on to the ocean. If there is not enough water flowing into the basin in which the lake lies so that it will run over the lowest point in the rim of land around it, then the materials which the streams are bringing cannot get out of the lake.

Great Salt Lake has streams running into it from the mountains upon different sides, but as it lies where the climate is very dry, so much of the water evaporates and goes off through the air that the lake

does not overflow its banks. Many, many years ago the climate of the region about the lake was more moist and the water overflowed and ran into the Snake river, a branch of the Columbia.

MONO LAKE, CALIFORNIA.
The Water of which is rich in Soda and Salt.

It has been so long a time since this overflow, that the salt which the streams are continually bringing in has now made the lake very salty.

In one way the ocean is very much like Great Salt Lake. It has no outlet. It fills the lowest places upon the earth and cannot flow anywhere else. For

long ages rivers have been flowing into the ocean from all the lands of the earth. The salt cannot get away in the clouds that rise from it and so it goes on accumulating. The ocean now contains nearly three pounds of salt in every hundred pounds of water.

SODA LAKE, NEVADA.
Showing Ponds where Water is Evaporated in making Soda.

Salt is prepared from sea water in many places by making enclosed ponds into which the water is allowed to flow as fast as it evaporates. By and by a very salty brine is formed, and as soon as it becomes saturated the salt crystallizes out and settles to the bottom. It is then shoveled out in piles. The most of our salt, however, comes from beds of rock salt which are exposed upon the surface or reached by deep wells.

If a bay of the ocean should be nearly separated from the main body of water, and the water in the bay continued to evaporate, there would finally be formed a strong brine. If occasionally the water of the ocean flowed in again, and then was finally shut off entirely from the bay the water in it would at last

CABIN OF ROCK SALT IN COLORADO DESERT.

dry up and leave a white deposit of salt over its surface. We really find such basins, in different parts of the world, filled with salt.

Some of the ancient beds of salt thus formed were covered with sands and clays and buried hundreds and even thousands of feet deep. Occasionally such beds are discovered by wells put down for water.

The water is so salty that it becomes valuable. It is pumped to the surface and allowed to evaporate in large, shallow pans from which the salt is then removed. Salt is made from brine on an extensive scale in New York and Michigan. It is reached by wells as the salt does not outcrop upon the surface. In Poland the salt beds are reached by shafts in which the men go down to mine the salt. They have excavated great chambers out of beds of solid rock salt.

When salt is quarried or mined it is sometimes clear as glass but often has some clay mixed with it. In the latter case it is dissolved in water and the clay settling to the bottom is thus separated. The clear salt has only to be ground to be ready for use.

In the deserts of southeastern California there are several deposits of rock salt. These dry, hot valleys where the salt lies used to be connected with the ocean through the Gulf of California. When the land rose the valleys were cut off from the gulf. There is little rainfall in this region and the water at last dried up and left the salt.

In this region near an old salt quarry there is a cabin made of rock salt. The pieces of salt are laid up to form the walls just as if they were ordinary rock. It rains so little that it will be many years before the cabin will be dissolved.

Salt is almost as soft as gypsum and has a glassy luster. If you break up a large cubical crystal you

will get many little ones just as perfect. This is because of the cubical cleavage which it exhibits. Rock salt is not always white. It may be tinted pink or gray by impurities.

Salt is very necessary as an article of food. It has a great importance in the arts, especially in the manufacture of soda.

WHERE BORAX AND SODA ARE MADE.

A large part of the soda which people use has been made from common salt after it has been treated with certain acids. In this chapter we want to talk about the soda which is prepared by nature.

Soda is composed of the element sodium in combination with carbonic acid. The proper name for this substance is sodium carbonate. Borax is a salt formed by the union of sodium and boracic acid. It used to be rather expensive, but has lately been found to exist, together with sodas, in great quantities in some of the ancient lake basins of eastern California and Nevada.

We are all familiar with the appearance and taste of soda. Borax is a white crystalline substance which when pulverized looks much like soda. It is distinguished from soda, however, in being much less soluble in water. Borax has important uses as a cleansing material. It is also used in soldering, in the manufacture of glass, and for various chemical purposes.

In eastern California and western Nevada there are broad desert valleys where the heat is intense during a part of the year. These valleys have no outlets, being shut in by mountains on all sides. In some of the valleys there are shallow lakes, but the most of

them are dry because of the slight rainfall upon the neighboring mountains.

Once the climate in these valleys was different. There was then a greater rainfall and many of the valleys had lakes in them. There was not rain enough, however, to cause the lakes to overflow, so

BORAX MARSH IN SOUTHEASTERN CALIFORNIA.

that the water could run away to the ocean. As a result of this condition all the mineral substances that the streams dissolved from the crumbling rocks were left in the lakes.

The constituents of the different lakes varied in

their proportions. The streams that flowed into one lake brought more salt, those flowing into another had more soda, while perhaps in a third there was more borax than anything else.

After a time the climate became dry, as it is today, and as there was not so much water to run into the lakes they began to shrink, and at last many of them dried up altogether. What do you suppose became of the various salts which the waters contained?

The salts remained mixed with the mud which had been gathering upon the bottom during the existence of the lakes. After the water disappeared the mud dried upon the surface, but below it was still moist. You would think if you walked over the surface of one of these old lake beds that there was no water for miles, but sink a well in the clay and you will be almost sure to get water. It would not be good water to drink, however, because of the different salts dissolved in it.

As we go over the deserts at the present time we find a white layer of these salts lying over the clayey floor of the old lakes. Because of the dry and heated air of these regions the water below the surface is drawn upward and evaporated. As it passes to the surface it takes along the various salts mixed with the mud and leaves them as a white coating upon the surface of the ground. This process is called efflorescence. You will see the same thing taking place upon the surface of a roll of butter on a dry day.

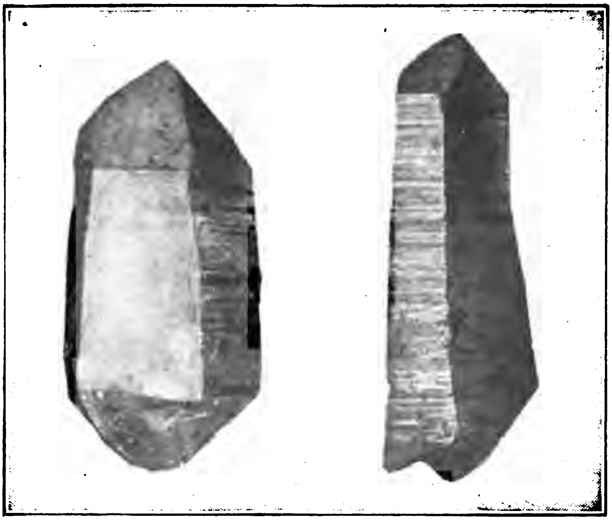
The salt water in the butter is drawn to the surface and evaporated, leaving little crystals of salt.

In this manner the old lake bottoms became covered with a layer or crust of soda, or borax, or salt, or perhaps all three more or less mixed.

On the borax marsh of southern California the borax is scraped from the surface and hauled to a group of buildings at the edge of the deposit. Here it is placed in tanks of hot water and dissolved. In this way the greater part of the impurities are gotten rid of, and the clear water containing the borax is drawn off. The water is then evaporated and the borax obtained is ready for shipment. It is placed upon great wagons and hauled fifty miles over the desert to the nearest railroad station.

Mono and Owens lakes in eastern California are rich in soda. It is obtained from the latter lake by enclosing portions of the shallow water with embankments. The water is allowed to evaporate, after which the soda is shoveled up and carried away.

Soda is also obtained from a small lake situated in a volcanic crater in central Nevada. The water, rich in soda, comes up in the bottom of the crater and keeps the lake at a constant height. This lake is very interesting and you would enjoy visiting it.



QUARTZ CRYSTALS.

CRYSTAL — CRYSTALLINE — AMORPHOUS.

At the head of our chapter there are three words that are used to describe minerals. Let us be sure that we understand what is meant by them.

Here is a group of quartz crystals. They are of different sizes; some are long and slender, others are short and thick. Can we detect anything in these forms which is common to them all? Yes, each of the crystals has six sides and at the end a six sided pyramid.

Wherever we find quartz crystals we may be sure that they will show the same number of sides as these which we have just examined. The shape of the crystal and the manner in which the sides are arranged is an expression of the grouping of the quartz molecules of which it is composed.

When you study chemistry you will find out more about molecules. When we speak of molecules of quartz we mean the smallest particles of quartz that can exist. We have never been able to see molecules even with a powerful microscope, but we are quite certain that there are such things.

The shape of the quartz crystal is determined by the arrangement of the tiny molecules. The crystal grew by additions upon the outside. Layer after layer of molecules was added, and in each layer they were always arranged in just the same way.

The regular shape which a mineral assumes when it is free to grow is a crystal. The molecules or tiny particles of each kind of mineral group themselves in a different manner, thus giving the different kinds of crystals.

Now it may happen, and it very often does, that a crystal has not room to grow into its natural shape. There may be other things in the way. Crystals of the same or different minerals may be growing near each other. We may suppose that some of these are little crystals of quartz, others of feldspar. Soon they crowd each other and by the time they have stopped growing they have not the form they would have had if farther apart.

Instead of having smooth, regular faces upon the outside, they have all sorts of shapes and look more like grains. This crowding, has, however, not affected the internal structure. In each the particles are arranged in a regular and systematic manner. We say that such a mass of one or more minerals is crystalline. This word refers to the internal structure, and not to the outer shape, as the word crystal does. We might give granite or marble as an example of rocks whose components are crystalline. We also say the rock is crystalline.

Under certain unfavorable conditions the molecules of minerals do not arrange themselves in regular order, and then we say that the mass is not crystalline but amorphous. The word amorphous means without form. The little particles, instead of group-

ing themselves in regular order like soldiers, row after row, rush together in a confused mass. They have no order. They are like a crowd of pushing boys.

Common glass is amorphous. The constituents of which it is composed cooled so quickly that it could not become crystalline. Obsidian or volcanic glass also is amorphous. The different components did not succeed in grouping themselves in molecules, and the molecules in minerals. If the lava had cooled slowly we might have found in it crystals of feldspar, quartz, mica, and perhaps hornblende.

SOME EXTERNAL CHARACTERS OF ROCKS AND MINERALS.

If you become interested in studying rocks and minerals you will be on the lookout wherever you go to see what you can find. They often exhibit curious shapes and markings and you will be sure to discover some of these. Let us have a little talk about some of the most interesting ones.

Upon the sandy bottom along the shores of ponds and lakes there are often to be found ripple marks caused by the movements of the little waves. I am sure you have seen them. They form a succession of furrows and ridges as though there had been waves in the sand. You will frequently find the same appearance upon the surface of a layer of sandstone. The sandstone was a bed of sand once, long ago, and had little ripples upon its surface just like those you find today.

Did you ever see the impressions made by the raindrops upon partly dried mud? They form little pits all over the surface. We sometimes find layers of slate with the same pitted surface. This teaches us that long ago it rained upon mud banks which afterwards were changed to slate.

Long ago, before the present animals lived upon the earth, there were others of many strange shapes.

Some of these enjoyed wading in the water or over the mud flats when the tide was out. If you walk across a bed of mud that is not too soft the impressions of your feet will remain very distinct. Now if the mud along some ancient shore over which animals of that time walked should be hardened to rock, the

CLAY STONES.

impressions of their feet would be preserved. Have you ever found any such strange looking tracks? They have been found in many places. The most remarkable ones come from a bed of sandstone in Connecticut.

Do you not think it very interesting that the hap-

CALCAREOUS TUFA.

Occasionally the nodules in rocks are hollow. Although rough upon the outside they are often beautiful within, either being lined with little crystals or exhibiting the bandings of agate. Such a hollow rock is called a geode.

We have learned that in limestone regions the

MUSHROOM ROCK, PYRAMID LAKE, NEVADA.
Formed by Deposit from Springs.

water is dissolving away particles of stone, making caverns which often can be followed for several miles. After being made these caverns are sometimes nearly filled by the same process. The water soaking through the roof brings a little lime with it, and deposits it

CALCAREOUS TUFA.

where the drops gather. After a time, as these deposits grow, they form little icicle-like bodies which look very odd suspended from the roof. In shape they are just like the icicles which gather along the eaves upon a warm winter day. These deposits that hang from the roofs of caves in this manner we call stalactites. The water drips from the ends of these to the floor and builds up deposits there. These sometimes meet those from the roof and form pillars. They are called stalagmites.

Interesting deposits of lime are often found about the mouths of springs that carry lime in solution. The lime is deposited upon anything in the water, such as twigs and leaves. In this way it builds up a porous mass called calcareous tufa. We often find impressions of leaves in the tufa.

In Pyramid lake, Nevada, there are wonderful tufa domes more than one hundred feet high formed from lime-bearing springs.

Minerals which are formed by deposition in water show surfaces of various kinds, but you had better look in some book upon mineralogy to find out about these.

COLUMNAR LAVA.

STRUCTURE OF ROCKS AND MINERALS.

The granules of calcite in a piece of marble are about the same size. The different components in a piece of granite do not vary greatly in size. We say that such rocks have a granular structure.

A rock may be composed of very coarse granules or of very fine ones. If they are so fine that we can scarcely distinguish them we say that the rock is massive. If the granules are loosely attached to each other so that the rock crumbles easily, we call it friable.

Volcanic rocks usually exhibit a structure very different from that we have just described. A por-

tion of the constituents in these rocks are very fine, so fine that we cannot tell what they are without the aid of a micropscope. In this fine part of the rock there are scattered large crystals of different minerals. These may be feldspar, quartz, mica, hornblende or augite. The rock looks as if these large crystals had been shaken into it. Such a structure we call porphyritic. The name porphyry was first given to a rock from Egypt. It was a compact red rock in which were scattered crystals of feldspar.

We have already learned that many volcanic rocks have round or elliptical pores scattered through them. These were left by the gases and steam which were mixed with the lava. When these pores are quite numerous the rock is said to be vesicular. If they form a large part of the rock we say that it is scoriaceous, that is, it looks like slag or scoria. Pumice stone has this character.

When volcanic rocks cool they frequently crack in such a manner as to form long columns having usually five sides. These may stand vertical or lie flat. In the latter case they resemble somewhat a pile of wood corded up. Such a structure we call columnar structure.

Water is slowly creeping through all rocks that have pores in them and carrying some mineral matter in solution. This mineral matter may be deposited in the cavities or pores and after a time entirely fill them. This matter may be lime, or quartz, or epidote. If it is quartz it results in little nodules of

agate. A rock which has had its cavities filled in this manner is said to have an amygdaloidal structure.

A rock or mineral is foliaceous or micaceous when it is made of lamellæ, permitting it to split more or less easily in one direction. The term schist, or the adjective schistose, is also given to rocks having this structure. When the rock splits in even layers it is said to be slaty.

A mineral is fibrous or columnar when it is composed of an aggregate of fibres or needles.

PORPHYRITIC ROCKS.
The White Crystals are Feldspar, the Dark Ones, Hornblende.

PHYSICAL PROPERTIES OF MINERALS.

In describing the minerals in the previous chapters we have used quite a number of terms which it may be hard to remember. Now let us arrange these terms in order, with their definitions.

We have found that minerals have certain characters by the aid of which we can describe them. They are soft or hard. They break with a rough fracture, or along smooth cleavage surfaces. They have different kinds of luster and different specific gravity.

Each kind of mineral always has the same properties. If we become familiar with these properties we shall have no trouble in recognizing the minerals that we find.

To aid in telling the hardness of minerals a series of minerals has been arranged, beginning with the softest and ending with the hardest.

The following is the scale of hardness:

(1) Talc:—Very soft, can be scratched easily with the finger nail.

(2) Gypsum:—Can be scratched with the finger nail, but not as easily as talc.

(3) Calcite:—Cannot be scratched with the finger nail. Easily scratched with the point of a knife.

(4) Fluorite: } Scratched with a knife but not
(5) Apatite: } easily.

(6) Orthoclase:—Can be scratched with difficulty by a knife blade; it will scratch glass.

(7) Quartz:—Cannot be scratched with a knife; will scratch glass.

(8) Topaz: }
(9) Corundum: } Cannot be scratched by quartz.
(10) Diamond: }

It is seldom that you will find anything much harder than quartz, so that there is little use for the last three numbers of the scale. After you have become accustomed to the common minerals you can readily tell about how hard any particular mineral is which you wish to determine.

Tenacity.

Tenacity is the resistance which bodies offer to breaking or crushing. Different minerals behave in different ways when they are struck. These ways are defined as follows:

Brittle:—Breaks easily; like sulphur.

Malleable:—Can be flattened into thin sheets with the hammer.

Ductile:—Can be drawn into threads. Gold, silver and copper are both malleable and ductile.

Flexible :— Retains its shape when bent, like scales of talc or satin spar. All malleable and ductile minerals are also flexible.

Elastic :—When bent will spring back, like mica and steel.

Luster.

When we speak of the luster of a mineral we mean the kind of light that is reflected from it.

We divide most minerals into two classes, those with metallic luster and those without. There are some minerals with a luster part way between and these we call sub-metallic.

The following are the important varieties of luster that we shall meet with :

Metallic luster :— This is the luster of all true metals, as gold, silver, and copper.

Sub-metallic luster :— As in biotite, mica, mineral coal, etc.

Vitreous luster :— Glass, quartz.

Pearly luster : —The luster of pearl, muscovite mica, talc.

Resinous luster :— The luster of resin as in sphalerite, sulphur.

Silky or satiny luster :— This is the luster of satin spar, asbestos.

Greasy or waxy luster :— Serpentine.

Dull luster :— Chalk, limonite, clay.

STREAK.

The streak of a mineral is the color of its powder. We look at a mineral and say that it has a certain color. If we scratch the mineral the powder will in many cases have a different color.

Some minerals let light pass through them. Others absorb or reflect all the light that comes to them.

A mineral is transparent when we can see a distinct image through it.

A mineral is translucent when light comes through but we can distinguish no object.

A mineral is opaque when it lets no light pass through. The different iron ores, as well as many minerals rich in iron, are opaque.

INDEX.

Miss Elizabeth J. Boyce, Teacher of Geography in Normal School, and Critic in Training Department, Mansfield, Pa.

I am greatly pleased with Dr. Fairbanks' book on "Home Geography." It meets so fully my own thought on that subject — it is such a happy departure from the old list of definitions and kindred work — that I should be very glad to see it given an extensive introduction into our common schools.

Maxwell Adams, Teacher of Geography, Chico Normal School, Chico, Cal.

I have looked through your "Home Geography for Primary Grades," and have decided to put it in the hands of the practice teachers in the training school. The pictures are exceptionally instructive. The subject matter is well chosen, and the questions are very suggestive. It would be a poor teacher, indeed, who would not gain suggestions for class work, and find places to put in actual experimental and field work, to supplement the book, thereby avoiding the lifeless formal study which so many of our text books encourage.

R. K. Buehrle, Supt. Schools, Lancaster, Pa.

I have examined Fairbanks' "Home Geography" and am very favorably impressed with its general character as an introduction to the scientific study of the subject. The typography and the illustrations leave little to be desired.

Samuel Weir, Ph. D., Principal, State Normal School, Clarion, Pa.

I find that "Home Geography for Primary Grades" is written in a very interesting style. The book is supplied with numerous handsome illustrations and it is printed in beautifully clear type and is strongly bound.

Fairbanks, H.W.
Stories of rocks and minerals.

79231

NAME	DATE	NAME	DATE
[illegible]	[illegible] 9 194[illegible]		
[illegible]	AUG 2 3 19[illegible]		
[illegible]	AUG 6 1948		
[illegible]	JAN 2 4 1951		
[illegible]	FEB 9 1951		
	FEB 2 6 195[illegible]		

79231